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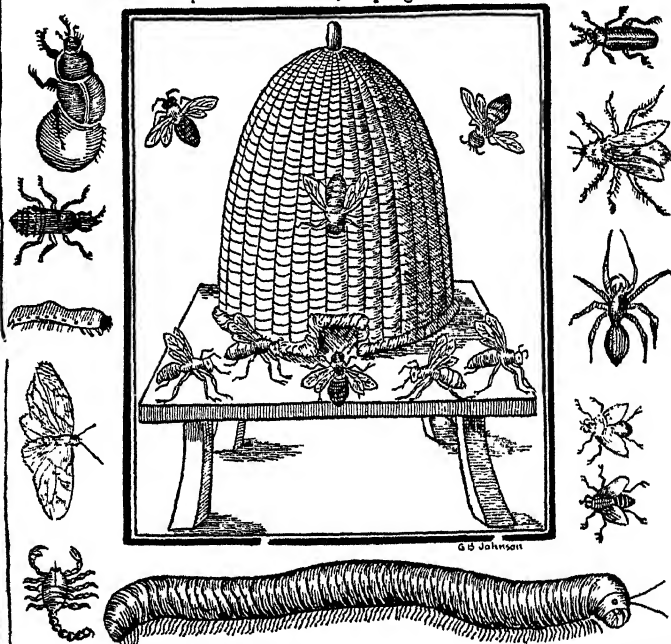
THOMAE PENNIO

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Tandem

THO. MOUFET : Londinâtis operâ sumptibusq; maximis concinnatum,
auctum, perfectum :

Et ad vivum expressis Iconibus supra quingentis illustratum.



Londini ex Officinâ typographicâ Thom. Cotes. Et venales extant apud Benjam. Allen,
indiverticulo, quod Anglicè dicitur Popes-head Alley. 1634.

TITLE PAGE OF THOMAS MOUFET'S "INSECTORUM SIVE MINIMORUM ANIMALIUM THEATRUM" (THEATRE OF INSECTS), LONDON, 1634. TRANSLATED INTO ENGLISH AND PUBLISHED BY TOPSELL IN 1658.

COLLEGE ENTOMOLOGY

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AGRICULTURAL EXPERIMENT STATION

UNIVERSITY OF CALIFORNIA

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PREFACE

In the preparation of this text the author has sought to furnish the essential facts about insects with which every well-informed person should be familiar. He has treated the subject from a world viewpoint rather than from a continental one. It is obvious that among the half million described species of insects many omissions are to be expected, but whatever species are here included have been selected for one of three reasons: (1) long associations with the human race; (2) some peculiarity in form, size, color, habits; or (3) interesting and typical examples of the family. Considerable attention has been given to simple and diversified treatment in the use of keys and illustrative materials in order to indicate the many possibilities available to the student and the teacher.

Although it is not specifically stated in the text, the author has desired to create a feeling of concern and good will towards insects in general. While a considerable number of species are detrimental to the economic welfare of man and many are most disturbing to his comfort and dangerous to his health, by far the greater number in no way inconvenience or interfere with him. As a matter of fact, not a few are important factors in the cross-pollination of plants; in furnishing food, raiment, and other commercial products for man's use; in providing the only means of subsistence for many birds, fishes, and other animals; in reducing and controlling many injurious insects and weeds; and in adding a delightful touch of color, charm, and interest to nature. The author hopes that the innumerable harmless species of insects will be treated with the same consideration and protection that is accorded to living things in general, of which they form so large a part.

In the systematic arrangement of the various categories, the author has taken an advanced viewpoint which appears to be consistent with present trends in the classification of insects. He has considered with great care every change involving the name of an order, family, or genus, and the whole is the product of much research, discussion, and progressive thinking. The rules and decisions of the International Commission of Zoological Nomenclature have been followed in so far as possible. In respect to higher categories the general concept is consistent with that expressed by Sabrosky (1938): (1) the oldest proposed family name, based on a valid included generic name, shall be recognized as the valid family name; (2) the valid name is the first used for the group, whether proposed originally for an order, group, family, subfamily, tribe, or other division, and regardless of the patronymic ending employed; (3) the family name is to be changed only when the type genus is found to be a homonym or a synonym and shall be based upon the same generic concept.

We should not overlook the fact that nationalism has played an important role in maintaining systems of classification, a situation that every entomologist should endeavor to correct.

The estimated numbers of described species in the various orders and families have been taken from all available sources. Those for certain orders are from Muesebeck, 1937.

In assigning authors and dates to the names of orders and families considerable difficulty has been experienced in determining priority, and there are no doubt errors in these debatable matters. Suggestions and corrections will be most welcome.

The illustrative material has received very thorough consideration, and a wide variety has been used. In view of the great value of such material in a textbook on entomology, it is regrettable that more drawings, photographs, and especially colored plates could not be included. Some of the figures have been selected as examples of early art, while many others indicate the progress in the development of entomological illustrations. It was originally planned to use marginal panel drawings to illustrate all keys, but since the number required was too great, only enough are included to show the possibilities of such small figures. For the most part the drawings are original, and a great many of them were prepared through the aid of the United States Work Projects and the National Youth Administration over a period of five years. Although many artists have contributed, I wish especially to acknowledge the work of Miss Dorothy G. Harris, Miss Virginia McPheter, Mrs. F. Abernathy, G. B. Johnson, and H. Schmidt. Authorship of borrowed illustrations, keys, and other specific information is indicated in each instance where it appears justifiable.

It is with much pleasure and satisfaction that I also acknowledge the help of my associates in the Division of Entomology and Parasitology, University of California. I am particularly grateful to W. B. Herms for making available the resources of the Division for preparation of the manuscript and illustrations, to E. Gorton Linsley for advice and help in connection with the many intricate and confusing problems relating to taxonomy and classifications, and to E. C. Van Dyke, S. B. Freeborn, S. F. Light, M. A. Stewart, S. F. Bailey, A. E. Michelbacher, R. E. Usinger, E. S. Ross, C. D. Michener, T. H. G. Aitken, N. Stahler, J. E. Hare, and others for help in many ways. H. S. King has aided greatly in reviewing and correcting the manuscript.

E. O. ESSIG

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COLLEGE ENTOMOLOGY

CHAPTER I

METAMORPHOSIS OF INSECTS

During development from the egg to the adult, the more primitive apterous insects change but little in general appearances except in size, while certain intermediate forms develop wing pads and assume other characteristics not greatly different from those of the adult, and the higher groups may pass through very remarkable stages altogether unlike the adult in form and habits. These changes during development are known as metamorphosis. They involve three stages, egg, young, and adult, in the primitive forms; three stages, egg, nymph or naiad, and adult, in the intermediate forms; and four distinct stages, egg, larva, pupa, and adult, in the higher forms. These changes involve growth and molting. The process of molting or shedding the skin is known as *ecdysis* (pl. *ecdyses*) and occurs in the immature stages of most insects and to some extent among adults of certain primitive species. This process consists in the formation of a new, soft, and elastic epidermis under the old, resulting in the rupturing of the latter (usually along the dorsal median line of the head and thorax) and the emergence of the insect from the old skin or *exuviae* (pl. *exuviae*). As a result, a considerable expansion of the body is permitted before the new epidermis becomes hardened and inelastic. The interval between ecdyses is the *stadium* (pl. *stadia*), and the age and form of the insect during a stadium is known as an *instar*. Thus the first-instar young or larva issues from the egg, the second instar follows the first ecdysis, the third instar follows the second ecdysis, and so on until maturity or the *imago* or *adult* condition is attained. The period from the formation or laying of the egg through all the stages to the death of the adult is called a *life cycle*.

TYPES OF METAMORPHOSES

- I. **Ametabola** or **Primitive** — in which no distinct external changes are evident, except in size; present in the **APTERYGOTA**: **PROTURA**, **THYSANURA**, **APTERA**, **COLLEMBOLA**. According to Imms, certain apterous forms in the **PHASMIDA**, **ISOPTERA**, and **ANOPLURA** might appropriately be placed in this group.
- II. **Metabola** — in which there are distinct changes during growth and development.
 1. **Paurometabola** — simple, gradual, or direct metamorphosis in which the immature forms resemble the adults except in size; the young are



FIG. 1. Carolus Linnaeus (Carl Linné). Born at Råshult, Sweden, May 23, 1707; died near Upsala, Sweden, January 10, 1778. Linnaeus, the first great modern systematic botanist and zoologist, established an exact system of naming all living natural objects known as the binomial system of nomenclature in which he assigned every plant and animal to a particular class, order, genus, and species. His method, which was quickly adopted, began a new era in the study and appreciation of nature. He devoted a great deal of his busy life to naming and describing insects, and consequently his name or the abbreviations L. and Linn. are attached to great numbers of the commonest and most important species of the entire world. His first great important general publication, *Systema Naturæ*, ed. 1, appeared in 1735 and contained the first list of the Linnæan orders of insects: COLEOPTERA, HEMIPTERA, ANGIOPTERA, and APTERA, which were grouped according to the form and structure of the wings. His seven orders of insects: COLEOPTERA, HEMIPTERA, LEPIDOPTERA, NEUROPTERA, HYMENOPTERA, DIPTERA, and AP-TERA were established in 1758 and were not materially altered or enlarged upon for many years.

His system of classifying insects is known as the alary or wing system. So important were his contributions that by common agreement the zoologists of the world have accepted the tenth edition of *Systema Naturæ* which appeared in 1758 as the starting point for all technical names of animals. Any such names antedating that publication are considered invalid.

Linnaeus was for years connected with the great University of Upsala at Upsala, Sweden, both as a student and as a teacher. His famous botanic garden, a portion of his collections, and his residence are still preserved there and he was interred in the Cathedral of Upsala. A splendid statue of him stands in the beautiful Humlegård Park at Stockholm. Most of his botanical collection and his insect collection belong to The Linnean Society of London, England, where they may be consulted by the biologists of the world.

His eager and unsparing pursuit of knowledge, his boundless mental and physical energy, his sagacity and charm of personality, his power to attract and retain students and followers, and his many great accomplishments made him the most outstanding figure in systematic biology since the time of the remarkable Greek philosopher and scientist, Aristotle (257–185 B. C.).

quite well developed when they leave the eggs and are usually active throughout the developmental period following eclosion; the immature winged forms early acquire wing pads and are known as *nymphs*. This condition occurs in most of the EXOPTERYGOTA or lower orders: DERMAPTERA, ORTHOPTERA, PHASMIDA, MANTODEA, BLATTARIA, ISOPTERA, CORRODENTIA, EMBIOPTERA,

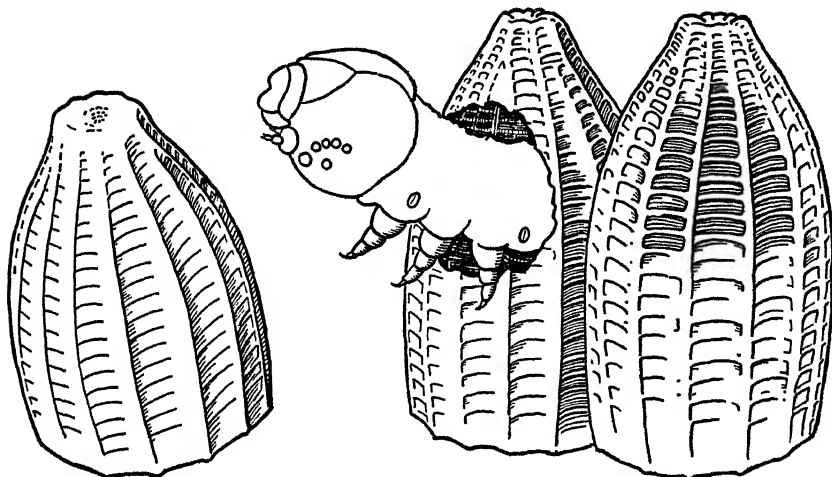


FIG. 2. Eggs of the European cabbage butterfly, *Pieris brassicae* (Linn.), showing a tiny caterpillar hatching from one of them. (After Pfurtscheller.)

TERA, THYSANOPTERA, ANOPLURA, MALLOPHAGA, HEMIPTERA, and others.

2. **Hemimetabola** — incomplete metamorphosis in which accessory organs or gills occur in the aquatic larvæ or *naiads*, whose adults are aërial; in the orders EPHEMERIDA, ODONATA, and PLECOPTERA.
3. **Holometabola** — complex, indirect, or complete metamorphosis in which the stages are egg, larva, pupa, and adult. The larvæ may assume several different forms and are very different from the pupal and adult stages. The pupæ are also variable in form; wings develop within the larval skin and may or may not be free in this stage; usually quiescent or with only certain movable abdominal segments; enclosed in cells, in silken cocoons, or in the last larval skin. This condition is found in the ENDOPTERYGOTA or higher orders: MECOPTERA, RAPHIIDODEA, NEUROPTERA, TRICHOPTERA, COLEOPTERA, STREPSIPTERA, DIPTERA, SIPHONAPTERA, LEPIDOPTERA, HYMENOPTERA.

Hypermetamorphosis — a kind of complex metamorphosis in which there are several types or instars of larvæ, including: a minute active first instar, a more or less robust and sluggish second instar, and a similar but apodous

third instar; represented in the NEUROPTERA (MANTISPIDÆ), COLEOPTERA, (MELOIDÆ, CARABIDÆ, STAPHYLINIDÆ, RHIPIDOPHORIDÆ), STREPSIPTERA, and parasitic DIPTERA (ACROCATIDÆ, BOMBYLIIDÆ, NEMESTRINIDÆ, TACHINIDÆ), and HYMENOPTERA (ICHNEUMONIDÆ, PTEROMALIDÆ, PERILAMPIDÆ, etc.).

STAGES IN METAMORPHOSIS

Egg. — All insects are produced from eggs or ova which consist of a yolk in cytoplasm surrounded in some cases by an inner *vitelline membrane* and an outer *chorion* or *shell* which affords protection to the contents. The shell is of two layers, a thick inner *endochorion* and an extremely thin outer *exochorion* composed of a chemical substance, *scleroprotein*, similar to chitin and also called *chorionin*. Since the eggs are formed and enclosed in the chorion within the body of the female before fertilization occurs, they are furnished with a polar *micropyle* consisting of one or more very minute openings by means of which the male sperm enters and fertilization takes place. Eggs of many insects are furnished with a lid or cap commonly referred to as the *operculum* by means of which the young escape.

Size. — Eggs vary from almost microscopic size, 0.1 mm. in length, to globular forms up to 3 mm. in diameter, and slender elongated types up to 5–6 mm. or more in length.

Shape — exceedingly variable, scale- or disk-like, hemispherical, conical, pyramidal, oval, reniform, globular, cylindrical, spindle-shaped, urn- and vase-like, and various other remarkable forms. Insect eggs have been employed as models in sculpture, ceramics, and decorations throughout the ages.

Colors — dull or bright, often cryptic and with more or less simple or intricate color patterns which are remarkably constant for the species.

Sculpturing. — Eggs of many insects are smooth and without reticulations or sculpturings of any kind. In others the shells are molded into very complex and beautiful patterns consisting of striæ, ridges, tiny spine-like and knob-like protuberances, net-like reticulations, punctures, and innumerable other devices. Eggs of certain shield bugs may have a row of spines or protuberances encircling the operculum.

Coverings and cases. — Egg laying is usually accompanied by the exudation of sticky or cement-like substances for attaching the eggs to one another and to the plant, for protecting the eggs, for serving as floats in aquatic forms, and for many other purposes. Eggs may be deposited in a matrix of cement or in an egg capsule or oötheca, covered with a felt-like material composed of cement and the hair and scales of the female's body; in floating rafts or in sacs; in gelatinous strings and masses; in thick silken webs; in woolly waxy secretions; and in many other ways.

Deposition. — Eggs are laid singly or in masses of only a few up to hundreds or even thousands, and over a period of years in the case of termites, ants, and

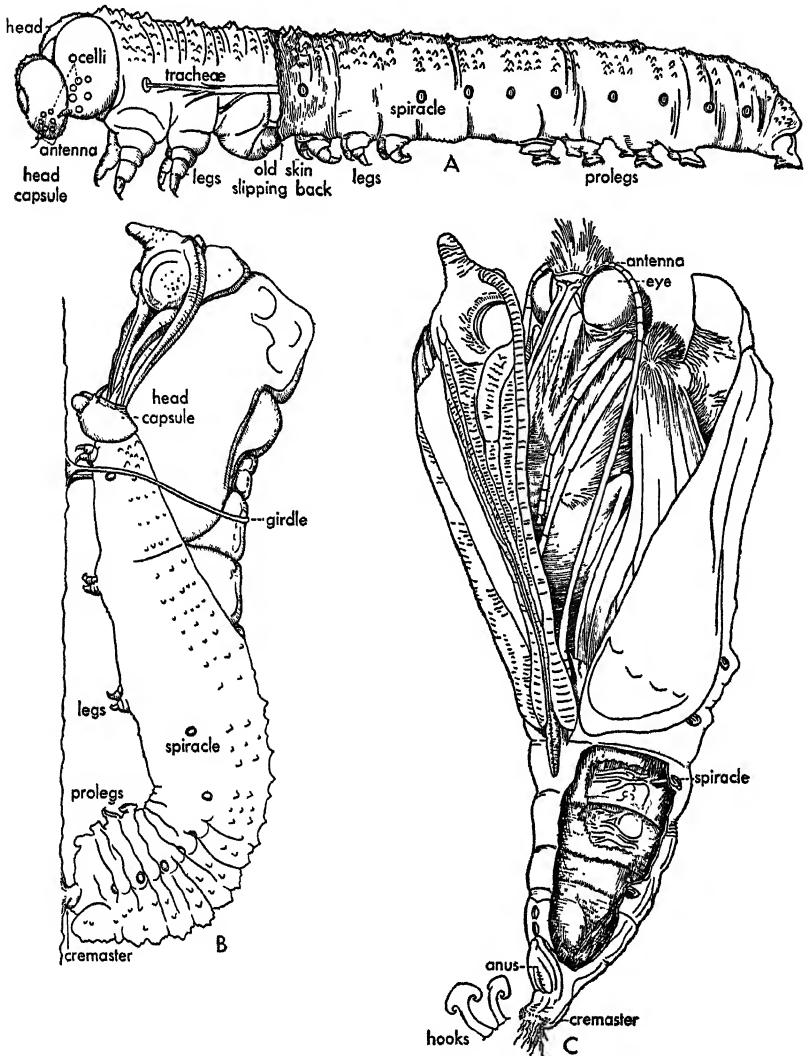


FIG. 3. Molting of the European cabbage butterfly. A, caterpillar shedding its skin and the linings of the main tracheal trunks; B, chrysalis emerging from the skin of the caterpillar and attached by the girdle and cremaster; C, adult butterfly emerging from the skin or exuviae of the chrysalis. (After Pfurtscheller.)

bees. They may be attached to the exterior of the host plants or other source of food; dropped on the soil or water; attached by short or long silken filaments; placed in cells; inserted in plant and animal tissues; grouped in rafts on the surface of the water; and in innumerable other manners.

Embryonic development. — The head is developed first and appears to be six-segmented; then the body segments appear, followed by the embryonic buds along the sides of the segments; and finally the coiled embryo.

Polyembryony. — In certain parasitic chalcid flies many embryos may develop from a single egg and give rise to adults of but one sex.

Hatching or eclosion. — Eggs hatch within the body (in *ovoviviparous females*) or outside the body (in *oviparous females*). The young escape from the egg by eating through the shell, by pulsating the body to burst the shell, and by the use of special hatching spines, teeth or ridges situated on the head and called egg-bursters. The eggs may hatch before leaving the body, as already noted, or they may hatch almost immediately after deposition. In most cases a period of embryonic development may require from a few days to several weeks before eclosion takes place. Eggs constitute a hibernating stage in many insects that live in the temperate and cooler regions and in rare cases they may not hatch for several years or until conditions are favorable to the young. Caterpillars often quickly develop within the eggs deposited in the summer or fall but do not emerge until the following spring.

Larva. — The young proceeding from the egg is properly known as the larva in all insects. It is the growing, feeding, and developing stage and usually covers the longest period in the life cycle. Upon hatching, some larvæ or *pro-nymphs* are enclosed in a thin membrane which soon ruptures and liberates the occupant. In general the tiny first-born larvæ take care of themselves and are wholly independent of their parents, but it must be said in fairness to the latter that they usually place the eggs either on or near a suitable food supply for the young. Those of certain social insects: termites, ants, wasps, and bees, feed and care for the young until they are fully grown, and many solitary wasps and bees provision cells in which the larvæ are supplied with sufficient food to meet all their requirements. Flies, whose eggs hatch within the bodies of the females, *larviposit* on meat, or in wounds of animals in the case of blowflies, or on the lips, skin, and in the nostrils of living animals in the case of botflies.

Molting — or shedding the outer skin of insects, has already been discussed but it should be kept in mind that ecdyses occur mostly during this developmental period and that every molt is a crisis in the life of the insect in that during this process the latter is helpless to flee or to resist its enemies and, what is even more important, it is often unable to free a limb or antenna from the skin, and perishes. Another important consideration is the fact that *regeneration* of parts, in so far as it occurs, takes place at the time of molting and is most successful in the younger stages, where several ecdyses follow the loss of an appendage or other member of the body, and becomes increasingly more difficult as development of the body proceeds. There are few chances of regeneration in the later larval and the pupal stages and none in the adult condition.

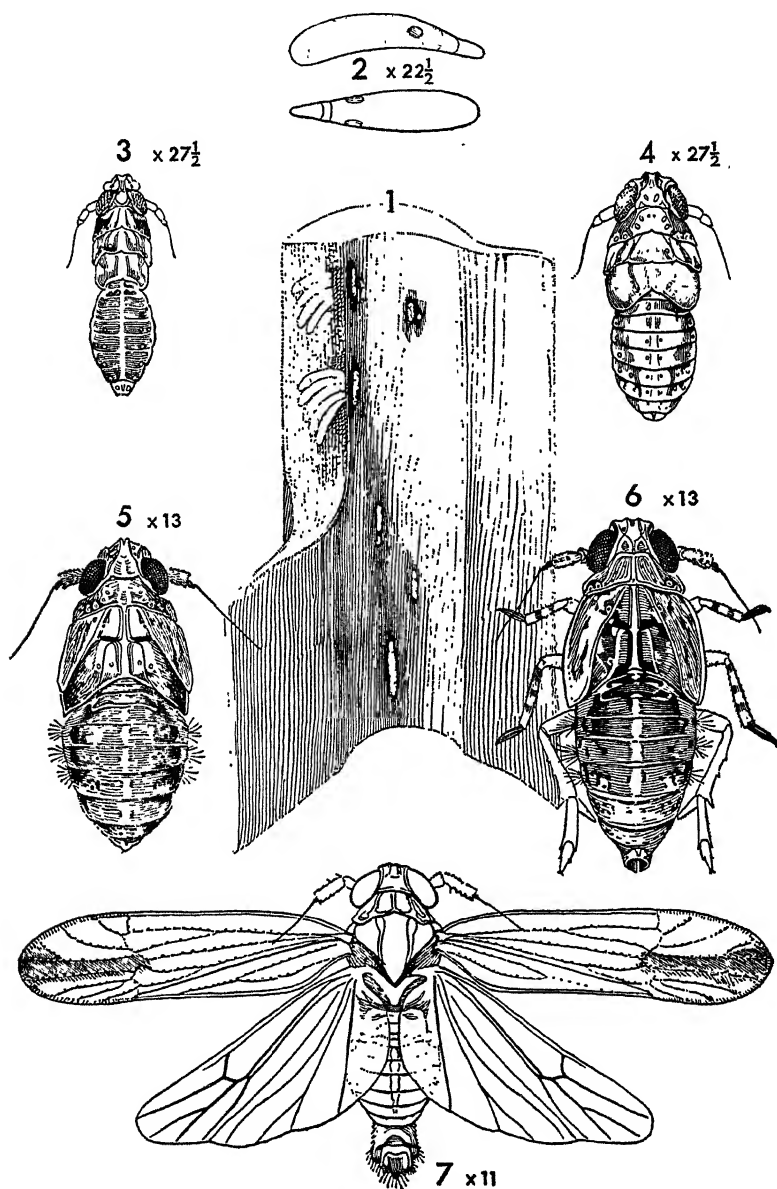


FIG. 4. Life history and metamorphosis of a paurometabolous insect, the sugar cane leafhopper, *Perkinsiella saccharicida* Kirkaldy. 1, eggs inserted into the midrib of a sugar cane leaf; 2, eggs; 3, 1st instar nymph; 4, 2nd instar nymph; 5, 3rd instar nymph; 6, 4th instar nymph; 7, adult with wings spread to show form and venation. (After Kirkaldy, 1906.)

Vestiture. — The larvæ, though they appear to be entirely smooth and naked, usually have some minute hairs and setæ. Many are thickly beset with setæ, hairs, and spines, some of which are branched. Tubercles, tail-like whips, respiratory tubes, and other appendages occur in specialized forms. Stinging hairs are not uncommon among the larvæ of many butterflies and moths.

Colors. — Larvæ which live in seclusion and in darkness, in the soil, in burrows in wood, mines, galls, and similar enclosures are usually white or pale yellowish or pinkish, while free-living and exposed forms are strongly pigmented and varicolored. Cryptic colors, simulating the background or food supply, are common. Many forms are arrayed in very beautiful patterns and are strikingly bizarre.

Shape. — Immature forms of insects occupy almost every conceivable nook in nature and are shaped accordingly. The generalized types are long, slender, and either flattened dorsally or more or less cylindrical in outline. Specialized forms are shaped like disks, limpets, spindles, the letters C and S, slugs, and a wide variety of other types.

Protective devices. — Many methods are employed by larvæ for protection against natural enemies and for environmental resistance. In addition to vestiture, already referred to, cases made to suit the size and shape of the individual are carried about throughout this stage and are often employed as places of pupation. They are constructed of soil, debris, silk, stones, calcareous materials, portions of leaves, sticks, and other plant substances. Fecal material may be used for cases or as a covering supported by anal fecal forks. Webs of small or huge size may serve as a protective canopy for individuals or large colonies of gregarious larvæ, and woolly waxy secretions may entirely hide aphids, coccids, certain few ladybird beetle larvæ, and numerous other insects.

TYPES OF LARVÆ

- I. *Oligopoda* — usually well developed at birth; normally with efficient thoracic legs, sometimes much reduced; with distinct body segmentation.
1. *Thysanuriform* — active, flattened, chitinous, free-living, mostly predacious species.
- (1) *Campodeiform* — elongated, with long or short sickle-like mandibles, and often well-developed antennæ and cerci. Represented by members in the orders EPHEMERIDA, ODONATA, PLECOPTERA, NEUROPTERA.
- (2) *Caraboid* — similar to campodeiform but usually more chitinized and with stronger mandibles and short antennæ and with or without cerci. Represented by the coleopterous families STAPHYLINIDÆ, CICINDELIDÆ, CARABIDÆ, DYTISCIDÆ, HYDROPHILIDÆ.
- (3) *Triunguloid* — minute active, spiny first instar larvæ of certain predacious beetles and stylops.
- (4) *Naupliiform* — minute first instar larvæ of *Platygaster* (HYMENOPTERA) with branching tails.

- (5) *Planidiiform* — the active first stage larvæ or planidia of certain dipterous parasitic flies and hymenopterous perilampids and chalcids.
2. *Eruciform* — sluggish, robust, cylindrical; thoracic legs well developed or vestigial, sometimes fossorial; mostly herbivorous and secluded, subterranean or living in burrows, in wood, in seeds, and in fruits.

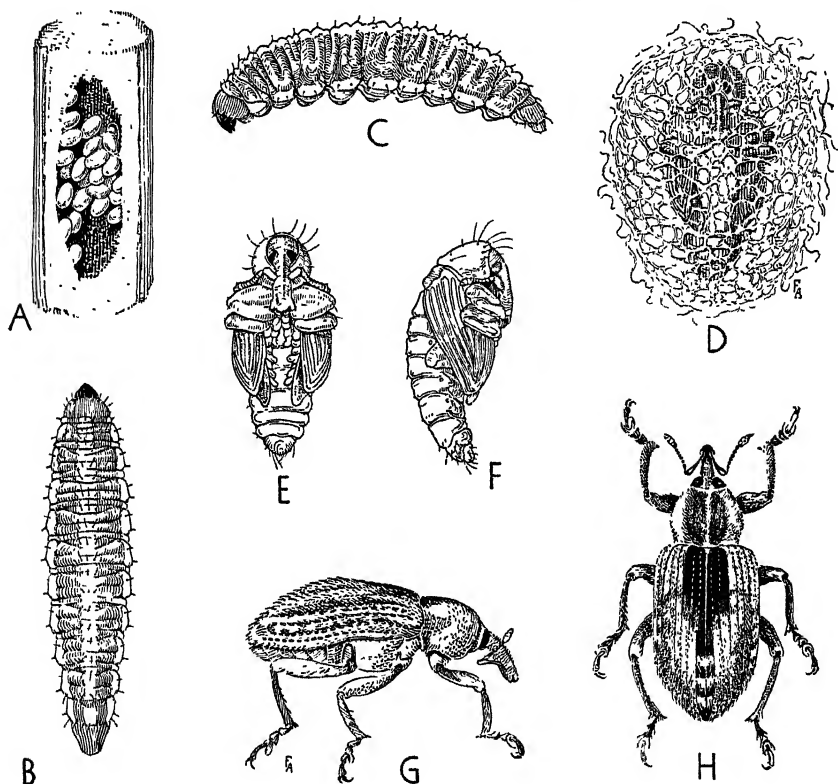


FIG. 5. Life history of a holometabolous insect, the alfalfa weevil, *Hypera postica* Gyllenhal. A, eggs exposed in the stem of alfalfa; B, dorsal and C, lateral aspects of full grown larva; D, pupa within lace-like cocoon; E, pupa removed from cocoon; F, lateral aspect of same; G, lateral and H, dorsal aspects of adult. (After Michelbacher, 1940.)

- (1) *Scarabæoid* — large, wrinkled, hairy species, often fossorial and living on the roots of plants and on decayed vegetation and dung; SCARABÆOIDEA.
- (2) *Cerambycoid* — large or small; straight; somewhat flattened or cylindrical; smooth and naked, distinctly segmented; mostly herbivorous; living in wood or in the soil; CERAMBYCIDÆ, BUPRESTIDÆ, ELATERIDÆ.

- II. **Polypoda** — mostly of the eruciform type and having abdominal legs or pseudopods; the herbivorous larvæ of LEPIDOPTERA and HYMENOPTERA (TENTHREDINOIDEA) and predacious MECOPTERA (PANORPIDÆ).
- III. **Protopoda** — larvæ which emerge early in their embryonic development and have the internal systems poorly developed. Represented by the early stages of members of the family PLATYGASTERIDÆ and other parasitic HYMENOPTERA.
- IV. **Apodous** — legless larvæ which are thought to have been derived from the oligopod condition; robust; C-shaped or spindle-shaped; with or without well-developed head; herbivorous, parasitic, or saprophagous.

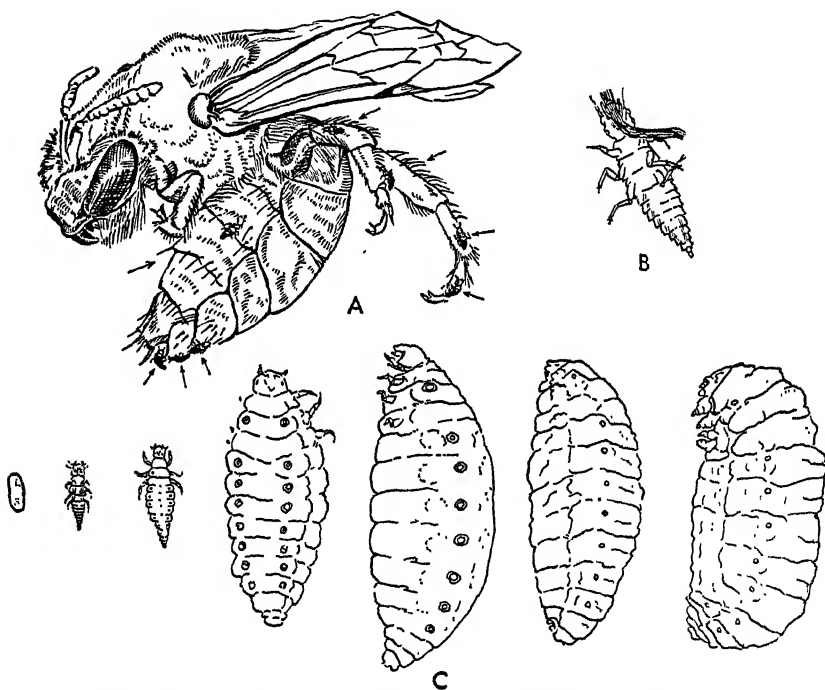


FIG. 6. Hypermetamorphosis in the blister beetle, *Tricrania sanguinipennis* (Say). A, minute 1st instar larvæ on various parts of the body of the bee, *Colleles rufithorax* Swenk; B, 1st instar larva clinging to a hair with its mandibles; C, egg and six successive instars of the larva showing change of form. (After Parker and Böving, 1924.)

1. **Curculionoid** — robust, C-shaped, with well-developed head; herbivorous aerial and subterranean plant and seed eaters. Represented by all RHYNCHOPHORA and all but the first instar in BRUCHIDÆ.
2. **Muscoid** — spindle-shaped or cylindrical and truncate maggots; headless; saprophagous, phytophagous, parasitic; secluded; most DIPTERA.

3. *Apoid* — robust; with well-developed head; cared for by daily feeding or in provisioned brood cells; represented by ants, bees, wasps, and certain parasitic forms.

Aquatic larvæ with tracheal gills occur generally in the orders TRICHOPTERA, EPHEMERIDA, ODONATA, and PLECOPTERA.

Dyar's Law. — A law propounded by H. G. Dyar states that the width of the head capsule of the larva follows a regular geometrical progression in the successive instars. This law is the result of studies of caterpillars, and its interpretation enables the student to determine the various instars by measuring the head. Exact measurements of other body parts in larvæ may be similarly employed.

Nymph — the active developing stage of paurometabolous insects already referred to. They are well represented in the various orders that have simple metamorphoses and especially in the HEMIPTERA. *Naiads* of aquatic insects are frequently referred to as nymphs.

Pupa (pl. *pupæ*; from the Latin *pupa*, a little girl, a doll; frequently translated as a baby and thought to refer to a swathed babe) — the inactive, reorganization stage of holometabolous insects. There is considerable variation in the pupæ, and the following important types are recognized:

1. *Primitive* or *pupa libera*, *exarate*, *free* — forms in which all appendages are free and somewhat resemble the adult condition; in some species they may become activated just prior to the final ecdysis. In NEUROPTERA, MECOPTERA, TRICHOPTERA; most COLEOPTERA; some DIPTERA; and a few LEPIDOPTERA (MICROPTERYGIDÆ) and HYMENOPTERA.
2. *Complex* or *pupa incompleta* — forms in which the appendages remain in separate sheaths and are only partly free or adhere to the body and the abdomen is capable of movement. Mosquito pupæ or "tumblers," pupæ of certain midges that are particularly active, and the more sluggish pupæ of most DIPTERA and LEPIDOPTERA and some COLEOPTERA belong to this type. These may be further segregated into:
 - (1) *Obtect* or *pupa obsecta* — forms in which the appendages are fused or tightly appressed to the body and are covered by an external skin; all parts immobile except either or both abdominal segments V and VI. Many of these pupæ or *chrysalids* have a posterior process or *cremaster* which may be furnished with apical hooks or with silken threads for attachment or anchorage. In higher LEPIDOPTERA.
 - (2) *Pupa coarctata* — in which the invisible pupa is enclosed in the last larval skin from which the adults or pupæ emerge through a circular rupture by means of specialized structures.

Cocoons. — Protective cases are spun of pure silk or of silk and various kinds of cement in which hair, scales, leaves, sticks, and debris may be incorporated. In some cases they are parchment-like and in others they are of a smooth calcareous substance and resemble birds' eggs. They are usually constructed by

the mature larvæ and in many cases may consist of the enlarged larval cases in which pupation takes place. The cocoons are variable in form and structure, being generally oval, globular, or somewhat cylindrical, and may be constructed of compactly woven strands of silk, of great masses of silk, spun like lace; ribbed, and often ornamented. Certain cocoons are usually very tight, some are lined with cement or varnish and are quite waterproof, while others are spun with an opening or exit hole at one end.

Cells. — Pupation frequently occurs in the larval cells of many insects. Such cells may be constructed of earth either below or above ground, of wood in

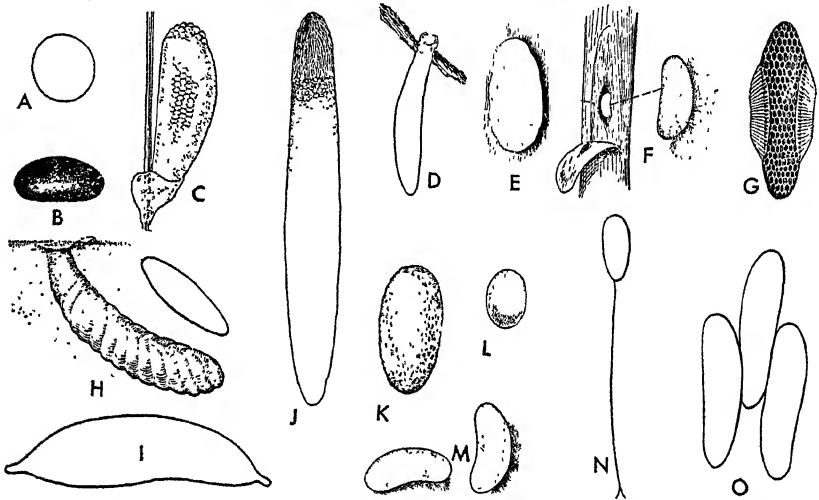


FIG. 7. Eggs of insects A, lucerne flea or collembolid, *Sminthurus viridis* (Linn.); B, green bug or grain aphid, *Toxoptera graminum* (Rondani) (after Walton, 1921); C, sucking cattle louse, *Solenopotes capillatus* Enderlein, attached to a hair (after Bishopp, 1921); D, apple capsid, *Paracaloris colon* (Say), in tissues of plant (after Knight, 1915); E, the ladybird beetle, *Hyperaspis binolata* Say (after Simanton, 1916); F, Phoenix billbug or weevil, *Sphenophorus phœniciensis* Chittenden (after Satterthwait, 1932); G, European malaria mosquito, *Anopheles maculipennis* Meigen (after Garman, 1917); H, grasshopper egg pod in the soil and a single egg pod (after Walton, 1916); I, ichneumon fly, *Diachasma tryoni* Cameron (after Pemberton and Willard, 1918); J, damsel fly, *Archilestes californica* McLachlan removed from water plant (after Kennedy, 1916); K, webbing clothes moth, *Tineola biselliella* Hummel (after H. C. Severin, 1921); L, dog flea, *Ctenocephalides canis* (Curtis) (after Howard, 1909); M, pear thrips, *Taniethrips inconsequens* (Uzel), removed from tissues of plant (after Foster and Jones); N, golden eye lacewing, *Chrysopa oculata* Say (after Smith, 1922); O, housefly, *Musca domestica* Linn. (after Howard, 1917)

burrows, of wax, and of paper. Case-bearing larvæ also usually pupate within their protective coverings, which may be enlarged to afford room and are closed to provide protection.

Adult or Imago — the final instar in the development of an insect in which all of the external characteristics have been attained and the internal systems fully matured. Insects in the adult form are usually referred to by such common names as grasshoppers, crickets, mayflies, lacewings, dragonflies, lice, bugs, beetles, weevils, flies, fleas, butterflies, moths, wasps, and bees.

CHAPTER II

THE ANATOMY OF INSECTS

EXTERNAL ANATOMY

A thorough knowledge of the external anatomy of insects is essential if the student in entomology is to understand the technical descriptions and be able to use keys and to write intelligently about these animals. Unfortunately, this chapter must be limited to generalities, but more specific information is included in connection with the various orders, families, genera, and species. For

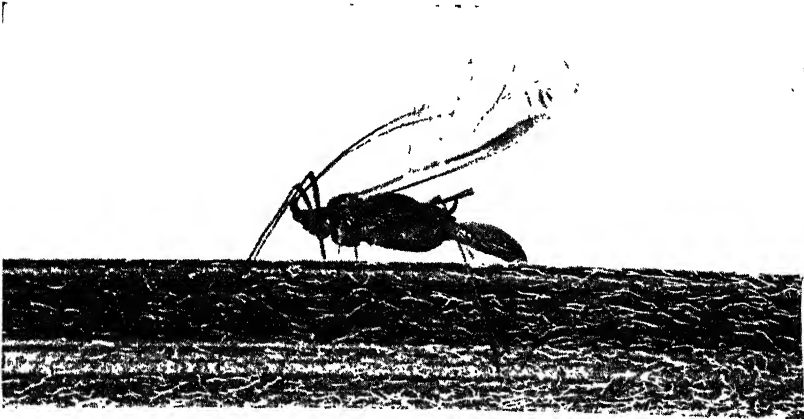


FIG. 8. Parthenogenetic female pea aphid, *Macrosiphum pisi* (Kalt.), giving birth to a living young. (Photo by S. B. Doten from *Insects of Western North America*.)

still more detailed information, the student is referred to the admirable work on the *Principles of Insect Morphology* by Snodgrass (1935), *Glossary of Entomology* by de la Torre-Bueno (1937), to the many general entomological texts, and to technical papers.

Exoskeleton. — The exoskeleton, integument, or body wall of an insect is a very remarkable structure which furnishes ample protection to the animal from moisture, dryness, disease organisms, certain animal parasites, shocks, temperature, and many other dangers. It is composed of relatively thin, rigid, hard, leathery, tough plates that are joined by thick or thin elastic and often fragile tissues; or, as in the case of many small insects like aphids and coccids, the exoskeleton may be composed of very thin, elastic, and fragile tissues with few plates and sutures. This outer wall of nonliving tissue is also referred to as

the *cuticle* and is the dried, more or less indestructible portion of insects preserved in collections.

Structure and composition of the cuticle.

Epicuticle — the very thin outer layer, not more than $1\ \mu$ thick, somewhat amber in color; impermeable.

Exocuticle — rather thick middle layer; colorless.

Endocuticle — thickest inner layer; colorless or partly amber; furnishes rigidity to the walls.

Composition. — These various layers are composed of from 20 to 50 per cent chitin, a nitrogen polysaccharide, together with proteins and other complex nonchitinous substances.

Renewal. — The discontinuous growth of insects is due to the fact that the exoskeleton is neither sufficiently renewed and extended nor elastic enough to accommodate for long the growing bodies of the immature insect, although it is rarely altered during mature stages. The entire outer integument is cast off from time to time in a process called *molting* or *ecdysis*. The cast cuticle or skin is the *exuviae*. The new exoskeleton is secreted by the *epidermal* (*hypodermal*) cells, a single layer of large cells just beneath the cuticle. In this renewal process a considerable amount of the chitin of the cuticle is absorbed before the skin is cast, retained until after molting, and utilized in the formation of the new integument.

Endoskeleton. — There are innumerable ingrowths from the cuticle for muscle attachments which are called *apodemes*. Groups of these are variously known as the *tenorium* or apodemes of the head; *phragmata*, apodemes of the dorsal plates or tergites; *lateral apodemes*, apodemes of the side plates or pleurites; and *furcæ*, apodemes of the ventral plates or sternites. These structures constitute the endoskeleton and are of value in the classification of certain groups of insects.

Segmentation. — The divisions or segmentation of the insect body in all the growing and adult stages are a distinctive characteristic of these small animals. In fact, the word insect is derived from *insectum*, referring to the incisions of the body. In the larvæ and pupæ the segmentation, though often distinct, is not so evident as in the adult with its three important body regions: head, thorax, and abdomen.

Head. — The somewhat oval or globular head is generally known as the *head capsule* because of its hard rigidity and toughness. It is thought to have been derived from no less than six primary segments and is composed of a number of sclerites separated by sutures. It supports organs of sight and sense — the eyes and antennæ — and of feeding — the mouth parts.

The sclerites derived from primitive segments are (1) *ocular*, (2) *antennal*, (3) *intercalary*, (4) *mandibular*, (5) *maxillary*, (6) *labial*.

Epicranial suture. — This important suture is a prominent line in the form of an inverted "Y" arising from the neck region as a single stem or median suture and branching on the vertex towards the bases of the antennæ. It divides

longitudinally the epicranium or top and back of the head into two epicranial plates or sclerites.

Occiput — part of the epicranium between the vertex and the neck.

Vertex — top of head between the compound eyes and behind the frons; usually carries the paired ocelli of orthopteroid insects and the three ocelli of other groups.

Frons — a single sclerite between and below the branches of the epicranial suture; carries the single frontal ocellus of orthopteroid insects.

Clypeus — a large double fused sclerite below or in front of the frons. It may be divided into an upper or *postclypeus* and a lower or *anteclypeus*.

Labrum or *upper lip* — a movable sclerite articulated to the lower margin of the clypeus and covering the mandibles and upper side of the mouth.

Genæ or *cheeks* — lateral regions back of and below the eyes; each may be divided longitudinally by an occipital suture into the *occiput* or dorsal area and the *postgena* or lateral region.

Cervicum or *neck* — the flexible area composed of the cervical sclerites and surrounding membrane, and encircling the posterior opening of the head or the *foramen magnum*.

Positions of the head. — The position of the head may be due to modifications of structure of the thorax or to methods of feeding. In relation to the rest of the body the head may be said to be one of the three following types:

Prognathous. — The main axis of the head is horizontal and the mouth parts are directed forwards. This type is found in most predacious larvæ and adult insects and may also be called the *thysanuriform* type.

Hypognathous. — The main axis of the head is vertical and the mouth parts are directed downwards and sometimes backwards. This condition occurs in adult insects in many orders and is especially common in many biting and chewing phytophagous insects and their larvæ. This may also be called the *orthopteroid* type.

Apistognathous. — The hypognathous type is modified to the extent that the mouth parts arise far back on the venter of the head and are directed downwards and backwards. This is the sucking or *hemipteroid* type.

Antennæ (sing. *antenna*). — The antennæ, feelers, or horns are a pair of segmented sensory organs located in front of or between and sometimes partly surrounded by the eyes, or they may arise from the sides of the face near the bases of the mandibles. They may be shorter than the head or several times as long as the body and are very greatly reduced in certain larvæ and absent in the order PROTURA. They not only vary greatly in size but also in form and structure, attaining especially great diversity among the COLEOPTERA. The commonly recognized forms are:

1. *Setiform* or *setaceous* — bristle-shaped; slender, tapering apically by reduction in the diameter of the segments; usually relatively short or very long. In COLEOPTERA, DIPTERA, LEPIDOPTERA.
2. *Filiform* — very slender and thread-like; segments of nearly equal di-

ameter; often very long. In OTHOPTERA, NEUROPTERA, COLEOPTERA, LEPIDOPTERA, and other orders.

3. *Moniliform* — necklace-like, consisting of a series of somewhat globular or oval bead-like segments of similar or variable sizes. In COLEOPTERA.
4. *Serrate* — saw-like or toothed, in which the outer margins of the segments are prolonged into tooth-like processes of variable sizes. In COLEOPTERA.

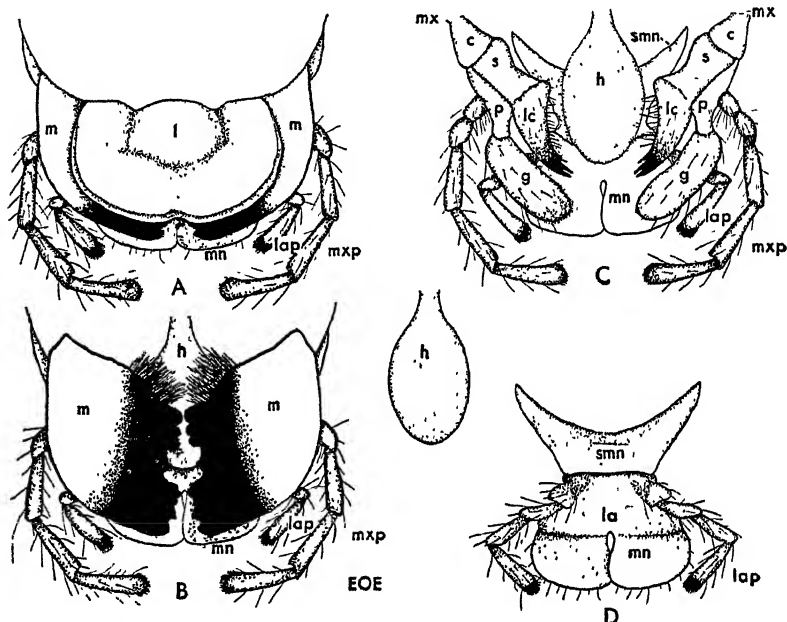


FIG. 9. Biting and chewing mouth parts of the devastating locust, *Melanoplus devastator* Scudder. A, dorsal or front aspect; B, same with labrum removed; C, same with labrum removed; D, labium; l, labrum or upper lip; m, mandibles or jaws; mx, maxillæ or second pair of jaws; c, cardo; s, stipes; lc, lacinia; p, palpifer; g, galca; mxp, maxillary palpi; h, hypopharynx or tongue; la, labium or lower lip; lap, labial palpi; mn, mentum; smn, submentum. (From *Insects of Western North America*.)

5. *Pectinate* — comb-like, in which one or two margins of the segments may be prolonged into slender processes like a comb. In COLEOPTERA, LEPIDOPTERA.
6. *Flabellate* — a pectinate type in which the processes are very long and together form a fan-shaped organ. In STREPSIPTERA.
7. *Plumose* — a pectinate type in which the processes are fine and are feather-like or plume-like. In DIPTERA, LEPIDOPTERA.
8. *Whorled* — usually a setiform, filiform, moniliform type with one or more whorls of hairs around each segment. In DIPTERA (NEMATOCERA).

9. *Clavate* — club-shaped, in which the segments increase in diameter apically. In HEMIPTERA, COLEOPTERA, LEPIDOPTERA, HYMENOPTERA.
10. *Capitate* — head-like, modified clavate type, in which the apical segments form a distinct somewhat globose enlargement or knob. In COLEOPTERA, LEPIDOPTERA, HYMENOPTERA.
11. *Lamellate* — leaf-like, modified capitate type in which the enlarged apical segments are lamellate and leaf-like and fold tightly or loosely together. Greatly developed in the SCARABÆOIDEA.
12. *Geniculate* — elbowed type, in which the first segment or *scape* is elongated and usually the longest of all; the second segment or *pedicel* is relatively short and variable in form; the remaining segments are variously named the *clava*, *clavola*, or *flagellum* and comprise: the *ring joints*, one or more small ring-like segments at the base of the clava; the *funicle* or series of small similar segments between the ring joints and the club; the *club* or enlarged apical segments. Geniculate antennæ are common in the RHYNCHOPHORA, CHALCIDOIDEA, FORMICOIDEA, and APOIDEA.
13. *Aristate* — modified form of capitate antennæ, in which the large apical portion terminates in a seta or bears a hair or *arista* which may be naked or hairy. Common in DIPTERA.

Sensoria (sing. *sensorium*). — The sensoria or organs of smell are developed on the antennæ of most insects. They vary in size, shape, and numbers and usually are much more abundant in males. They may consist of a circular or oval pit or opening covered with a thin transparent membrane and are well known in certain families of the HOMOPTERA. *Sensilla* are minute sense organs of which there are many types consisting of cavities, cones or pegs, domes, spines or bristles, plates, and rods, some of which occur in all orders and are not confined to the antennæ.

Compound or *faceted eyes*. — The most important organs of sight are present in most adult insects and are situated one on each side of the head; divided into a few or hundreds or even thousands of facets or small hexagonal areas, each of which is a lens-like unit of sight known as an *ommatidium*. The numbers of facets vary from six to nine in ants up to 28,000 or more in dragonflies (Tillyard, Imms). The image is thought to be a mosaic pattern which specially permits the perception of moving objects.

Ocelli (sing. *ocellus*) or simple eyes — small simple eyes common to both immature and mature insects. In larvæ of caterpillars they may be arranged in a series on each side of the head, while in adults there are usually two or three present, arranged in a triangle or row on the vertex as in many dipterous and hymenopterous forms or two dorsally near the compound eyes and one on the front or frons as in the case of grasshoppers, aphids, and many others. They are thought to serve to distinguish a faint image and light from darkness. Many larvæ and adult insects have neither compound nor simple eyes.

Mouth Parts. — The most important organs of the head, the mouth parts, present many specializations in form and development and are always difficult for beginning students to comprehend. As a matter of fact, a comprehensive comparative study of the various organs may require a lifetime. While there is great specialization in certain groups, at least two types are more or less easily recognized in their simple outward forms. The most generalized is the *mandibulate* or *biting type* which forms the basis with which all others are compared.

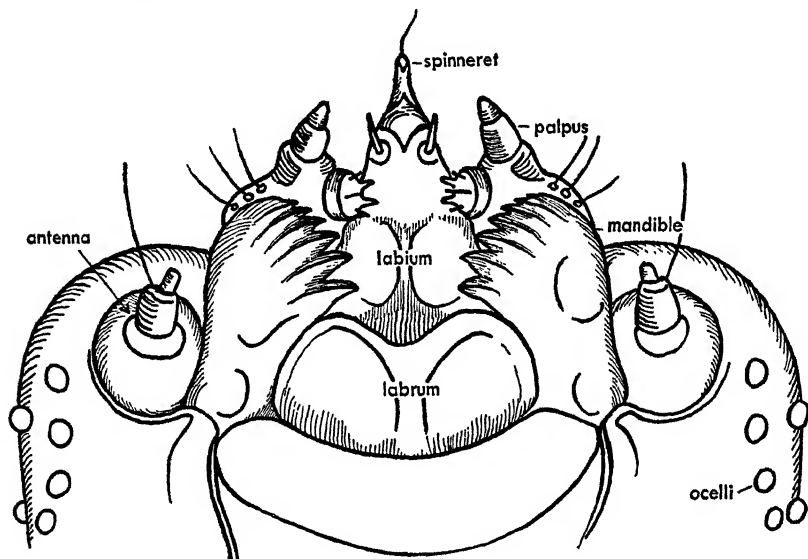


FIG. 10. Biting mouth parts of the caterpillar of the European cabbage butterfly, *Pieris brassicae* (Linn.). (After Pfurtscheller.)

Little is to be discovered from the exterior, but when a careful examination is undertaken, the position, form, and structure of the important parts and their appendages are simple enough. Those of the grasshopper are typical and usually selected for the purpose. The removal for study is best accomplished as indicated in Fig. 9, and the separate parts are illustrated in practically every entomological text.

Labrum or upper lip — the front terminal head sclerite, hinged to the clypeus; variable in size and shape; oval, rectangular, triangular, or linear; dorsal covering of the buccal cavity.

Mandibles or true jaws — paired, strongly sclerotized, piercing, biting, and chewing organs; variable in size and shape: stylet-like (flies, fleas), sickle-shaped and grooved (lacewings, beetles), formidable organs of defense (termites, beetles, ants), grotesquely enlarged (stag beetles), greatly reduced (butterflies, moths), absent (certain caddis flies, flies, butterflies). They articulate laterally and move inward to meet in the middle. In phytophagous forms the

mandibles may be bluntly toothed whereas in many carnivorous insects they are sharp.

Maxillæ or *second pair of jaws* — complicated structures composed of a number of distinct or partly fused segments forming organs for mastication and for holding food and conveying it into the mouth. The different parts are:

Cardo or *hinge* — the basal segment which is usually short and triangular and may be the only part attached to the head. *Stipes* or *basal stalk* — the second outer segment; articulating with the *cardo*; triangular or elongated and pointed; may be fused with the *subgalea* or *palpifer*. *Palpifer* or *palpus bearer* — the third outer segment bearing the palpus; often small and triangular. *Maxillary palpi* — a pair of conspicuous sensory appendages, usually three- to five-segmented or variable from one- to six-segmented; they aid in examining, holding, and conveying food into the mouth. *Subgalea* or *helmet bearer* — the first inner segment beyond the *cardo*; may be fused with the *lacinia* or with the *stipes* or be absent. *Galea* or *helmet* — a one- or two-segmented appendage also known as the outer, upper, or superior lobe and quite variable, being hood-like and somewhat covering the *lacinia*, or palpus-like. *Lacinia* or *blade* — the conspicuous elongated inner lobe serving as a cutting, chewing, and feeding organ; bearing a few spines or teeth or a comb-like or brush-like growth on the inner margins; frequently with a small apical finger-like segment which is an articulating claw in the tiger beetles.

Prostheca — a flexible, blade-like fringed plate similar to the *lacinia* and attached near the base of the mandibles in a few insects.

Hypopharynx, *lingula*, or *tongue* — a fleshy or awl-like tongue lying on the floor of the mouth; bearing the outlet of the salivary ducts; sometimes used for piercing in feeding. *Superlinguæ*, *paragnatha*, or *maxillulæ* — a pair of lateral lobes of the hypopharynx occurring in adults and larvæ of a number of orders.

Labium or *lower lip* — a complex structure forming the back or floor of the mouth and consisting of a number of variable parts including: *Submentum* or *base* — the larger basal portion which is often crescent-shaped posteriorly. *Mentum* — the forward portion separated from the submentum by the transverse labial suture. *Prementrum* — a divided lobe in front of the mentum bearing apically the *palpifers*, narrow sclerites supporting the labial palpi. *Labial palpi* — paired sensory organs similar to the maxillary palpi but smaller and with one to four segments. *Ligula* — the divided distal portion of the *prementum* and supporting apically an inner pair of *paraglossæ*. These organs are greatly modified and elongated in the bees.

Epipharynx — a membranous or chitinous fold attached to the inner wall of the labrum and to the upper surface of the labium and lining the buccal cavity; variable in form and often divided into a number of regions, especially in the larvæ of scarabæoid beetles.

Thorax. — The thorax or second body region is a complex structure composed of a large number of sclerites separated by sutures and held together by strong membranous tissues. This, the most muscular region, supports the large mus-

cles of the legs and wings. The great specialization that takes place in the thorax is due to the development of muscle tissue.

Regions. — In most adult insects three thoracic regions are discernible:

Prothorax — the anterior arthromere which is exceedingly variable in size and shape, being very greatly reduced in certain species and very greatly lengthened in others; it bears the forelegs and frequently a pair of spiracles. *Mesothorax* — the median arthromere which is normally enlarged

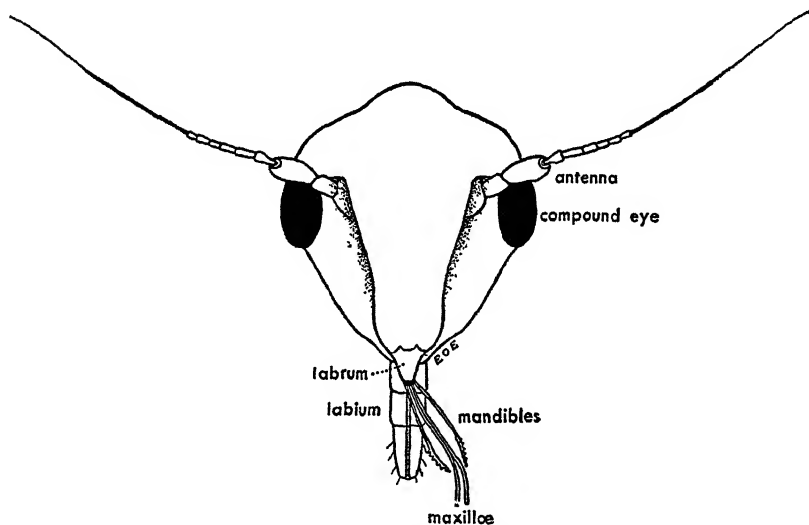


FIG. 11. Head and sucking mouth parts of the grape leafhopper, *Erythroneura comes* (Say). (From *Insects of Western North America*.)

and muscular and bears the large fore pair of wings and the middle legs.

Metathorax — the posterior arthromere; somewhat smaller than the mesothorax; bearing the hind pair of wings and the longer and often larger hind pair of legs.

Sclerites and intersegmental plates of the thorax:

Tergites — the *tergum* is usually a simple undivided dorsal sclerite or *notum*. Thus in the thorax there are the *pronotum*, *mesonotum*, and *metanotum*. The *notum* may appear as two smaller sclerites, the *scutum* and the *postnotum* or *postscutellum*, or as three sclerites, the *prescutum*, *scutum*, *scutellum*. The *patagia* are flat lobe-like or stalked structures produced laterally and backwards from the pronotum in mosquitoes, moths, and butterflies, and the *parapsides* result from the division of the scutum of the mesonotum into two parts in chalcid flies.

Pleurites or the lateral, usually oblique, sclerites are separated by the pleural suture into two main divisions: (1) *Episternum* or anterior larger sclerite which may in certain cases be demarked into *preepisternum*, a sclerite ante-

rior to the epimeron; *supra-episternum* or *anepisternum*, the upper sclerite; *infra-episternum* or *katepisternum*, the lower sclerite; *sternopleuron*, the lower plate formed by the fusion of the episternum and the sternum (Imms); *prepectus*, the anterior marginal sclerite of the episternum of the mesothorax in ichneumonoid parasites; *paraptera*, a pair of small sclerites between the upper margins of the episternum and the bases of the wings, each divisible into a *preparapteron* and *postparapteron*. (2) *Epimeron* or posterior and usually smaller sclerite which is divisible into the *supra-epimeron*, *anepimeron*, or *pteropleuron*, the upper sclerite of the epimeron in the mesothorax, and the *infra-epimeron* or *katepimeron*, the lower sclerite of the epimeron.

Sternites or ventral intersegmental areas usually between the coxæ:

Eusternum — the area exclusive of the *spinasternum* or spina-bearing sclerites, of the poststernum and mesosternum; *presternum*, the sclerite in front of and connected with the eusternum; *sternellum*, the sclerite connecting posteriorly with the eusternum; *poststernellum*, a sclerite just behind the sternellum (may be fused with the preceding or with the sclerite behind it); *laterosternites*, the sclerites at the sides of the eusternum which meet the pleurites; *spinasternum*, spina-bearing sclerite between the intersegmental areas of the prothorax and the mesothorax; may be fused with the adjoining sclerites.

Acetabula or *coxal cavities* — openings surrounding the coxæ; they are said to be *closed* when the epimeron extends to the prosternum and no openings are present or *open* when the epimeron does not extend to close the cavities.

Spiracles — paired spiracular or breathing openings of the tracheæ of the respiratory system; present in most adult and larval forms, absent in certain highly specialized forms as the larvæ of some parasitic HYMENOPTERA; usually two pairs are present on the sides of the thorax, the first pair in the area between the prothorax and mesothorax and the second pair similarly located between the mesothorax and the metathorax.

Peritreme — a small sclerite bearing a spiracle.

Legs. — Three pairs of true legs are present in most adult and larval stages of insects. Larvæ may be apodous, as in some beetles, weevils, flies, moths, and hymenopterous parasites, or they may possess true or thoracic legs together with from two to 10 pairs of prolegs or abdominal legs. The true legs of the adults are variable in length but fairly constant in form and general structure except that in specialized forms they may be greatly modified or even reduced. Among the common types of legs are those for running or *cursorial*, for digging or *fossorial*, for swimming or *natatorial*, and for holding prey or *raptorial*. They are also adapted for stridulating, for holding the female during mating, and for drumming. In certain of these modifications, including digging, grasping prey, and holding the female, the forelegs are most involved, whereas in swimming the middle and hind pairs are specially adapted. The parts of the leg follow: *Coxa* (pl. *coxæ*) — or proximal segment is variable in size and form but is usually more or less subglobular; set into the coxal cavity or *acetabulum* of the body as a

feebly articulating or fixed segment and acts as the pivoting joint; may be single or divided into two sclerites, the *coxal process* and the *trochanterin*, and may rarely also possess an inner sclerite, the *antecoxal piece*. The *subcoxa* (*precoxa*, *pretrochantin*) is the single basal segment in certain primitive forms. *Stylus* (pl. *styli*) is a small finger-like appendage on the inner margin of each coxa of *Machilis*; also borne on the large ventral abdominal plates or coxites of *Machilis* and *Lepisma* in the order THYSANURA.

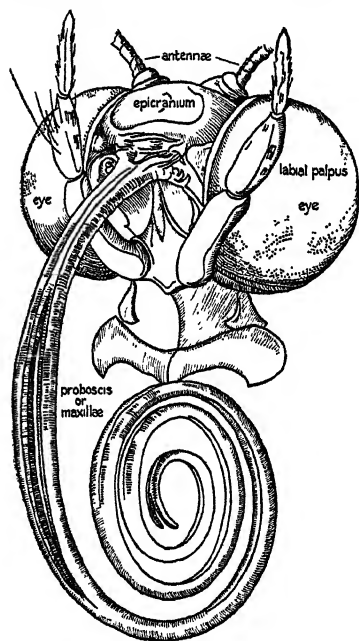
Similar one- or two-segmented organs occur on the first three abdominal segments in the order PROTURA.

Trochanter — second division of the leg; short and simple in most insects or long and divided into two parts in mature and immature ODONATA and in larvæ of certain COLEOPTERA and apparently divided (one part is end of femur) in parasitic HYMENOPTERA; frequently triangular, with the femur articulating on the outer surface; large and somewhat ovoid in the hind legs of carabid beetles

Femur (pl. *femora*) or *merus* — third and in most adult insects the strongest and most prominent segment; usually somewhat thickened; those of the hind legs greatly enlarged in such jumping insects as grasshoppers, crickets, katydids, beetles, and fleas.

Tibia (pl. *tibiæ*) or *carpus* — fourth division; usually as long as or longer and slenderer than the femur; cylindrical or compressed and dilated posteriorly; outer margin furnished with spines or swimming hairs; often modified for capturing and

FIG. 12. Head and mouth parts of the European cabbage butterfly, *Pieris brassicæ* (Linn.), showing the remarkable curled proboscis or maxillæ. (After Pfurtscheller.)



holding prey, digging in the soil or in wood, swimming and other purposes; with one or two pairs of movable spurs referred to as *middle spurs* or *apical spurs*. *Strigilis* or *antenna cleaner* — a large articulated curved comb-like spur on the inner extremity of the fore tibia opposing a comb of hairs on the *metatarsus* in bees. *Epiphysis* — a strigilis-like spur or pad on the inner extremity of the fore tibiæ in certain LEPIDOPTERA.

Tarsus (pl. *tarsi*) — the extremity of the leg; a single segment in primitive PROTURA and THYSANURA but comprising one to five segments or rarely absent in higher orders; the segments cylindrical or broad and pad-like, slender and long or wide and short; sometimes hairy or spined; metatarsus or basal segment often much larger than rest and specialized to oppose the *strigilis* to form the antenna cleaner on the forelegs and to complete partly the *corbicula* or

pollen basket on the hind legs of bees. *Pretarsus* — in some insects a small distal portion of the apical segment bearing the claws, pulvilli, or empodia.

Claws, tarsal claws, ungues — one or two curved, simple, toothed, or bifid claws used chiefly for clinging to plants, animal hosts, and other objects; opposing a tooth on the tibiae in the ANOPLURA.

Pulvillus (pl. *pulvilli*) or *onychium* — slender or pad-like cushions on the ventral tarsal segments or a pair beneath the claws of DIPTERA; may be provided with hollow *tenant hairs* for exuding adhesive secretions to aid in clinging to surfaces.

Empodium (pl. *empodia*) — a small appendage between the apical pulvilli and associated with the claws in DIPTERA.

Arolium (pl. *arolia*) — a pad-like appendage between the claws of orthopteroïd insects.

Wings. — Insects are apterous, brachypterous, or fully winged. There are usually two pairs of wings: primary or fore pair and secondary or hind pair. The primary wings are usually considerably larger than the secondaries although in a number of orders both pairs are nearly equal in size. In certain few EPHEMERIDA there is but a single pair while in the DIPTERA the secondary wings are represented by a pair of small capitate appendages or *halteres*, commonly referred to as *balancers* or *poisers*. In the brachypterous forms the wings are often shortened or stub-like. In various groups one or both sexes may be either winged or apterous. In others the wings are atrophied or rudimentary.

The wings are bag-like membranous structures developed as lateral extensions of the mesonotum and metanotum. They are articulated to the sides of the notum by means of the *anterior* and *posterior calli* of the wing bases coupled to the *anterior* and *posterior axillaries* of the notum, aided by the *pleural wing process* beneath and the two *paraptera*, one on each side of the base. The *axillary membrane* is attached to the base of the wing. It extends from the tegulae to the axillary cord and surrounds the small axillaries or axillary sclerites referred to above. The wings consist of a double membrane which may be smooth and naked or covered with *microtrichia*, minute fixed hairs, *aculeæ*, microscopic microtrichia, or *macrotrichia*, larger movable hairs and scales. The otherwise fragile organs of flight are traversed by tracheæ of the respiratory system and strengthened by a simple or complicated system of *veins* or *nervures* which are sclerotized arches on either membrane over the tracheæ or disposed longitudinally in a system of branches or longitudinally and transversely into a fine or coarse network. *Alula* (pl. *alulæ*) or *squama* (pl. *squamæ*) — one or more membranous lobes or scale-like expansions of the basal axillary membrane which fold beneath the bases of the closed wings of COLEOPTERA and DIPTERA. *Aileron* and *alulet* may be used in a similar sense, and *calypter* is employed when these lobes cover the halteres in DIPTERA.

Axillary excision — a notch near the base of the inner hind margin of the wing which separates the small *posterior* or *basal lobe* from the rest of the wing.

Wing couplings. — The two pairs of insect wings are held together in flight by various coupling devices. One of the commonest types consists of one or

more hooks or *hamuli* arranged in a row on the outer costal margin of the hind wings which engage a fold on the middle hind margin of the fore wings. In the NEUROPTERA, TRICHOPTERA, and other insects, the *fibula*, a process or lobe on the upper base of the fore wing, extends back over and clasps an elevation on the base of the hind wing and unites them in flight. In moths of the family HEPIALIDÆ, the *jugum*, a slender finger-like posterior lobe of the fore wing, engages the undersurface of the costal margin of the hind wing, while in many moths a *frenulum*, a spine or group of bristles on the humeral angle of the hind wing, engages the *frenulum hook* or fold at the posterior base of the fore wing.

Primary longitudinal veins:

Costa (C) — forms the front or costal margin of the wing; without branches.

Subcosta (*submarginal*) (Sc) — extends along the front margin; unbranched or two-branched; terminating on the costal margin.

Radius (R) — extends to the costal margin about half way and its branches continue to the apex of the wing; five-branched, giving rise to the *radial sector* (R_s) and to R_1 to R_5 .

Media (M) — occupies the medial area of the wing; four-branched, giving rise to M_1 to M_3 , M_{1+2} , etc.

Cubitus (Cu) — occupies the area posterior to the media and extends to the margins of the wing, giving rise to Cu_1 , Cu_2 , etc.

Anal (A) — usually one or two, rarely three, simple veins in the anal area designated as 1A, 2A, 3A.

Secondary longitudinal veins:

Marginal — a portion of the radius just basad to the stigma or stigmal region in HYMENOPTERA.

Stigmal — a short, straight or curved vein arising from the inner margin of the stigma and extending inwards in HYMENOPTERA.

Post marginal — a short vein extending apically from the stigma or stigmal region in HYMENOPTERA.

Important crossveins:

humeral (h) — a very short vein that connects the costa (C) and subcosta (Sc) in the basal or humeral region.

radial (r) — connects the branch R_1 of the radius (R) and the radial sector (R_s).

sectorial (s) — connects the stem of R_{2+3} to R_{4+5} or R_3 to R_4 .

radio-medial (r-m) — connects radius (R) and the media (M); near the middle of the wing.

medial (m) — connects M_2 and M_3 .

medio-cubital (m-cu) — connects the media (M) and the cubitus (Cu).

arculus — a small basal vein connects the radius (R) and the media (M) in ODONATA; a point where the cubitus meets the margin in many other orders.

Cells — the areas enclosed or partly enclosed by the veins; the proximal ones are called basal cells and the distal ones the distal cells. The names of the indi-

WING CELLS

	<i>Comstock-Needham</i>		<i>Tillyard</i>	
<i>Old name</i>	<i>Common name</i>	<i>Notation</i>	<i>Common name</i>	<i>Notation</i>
	costal	C	costal	c
Costal	subcostal	Sc	1st subcostal	1sc
	"	Sc ₁	2nd subcostal	2sc
Stigma	stigma, pterostigma	pt	pterostigma	pt
1st cubital	1st cubital	R	1st radial	1r
1st radial 1st submarginal	radial	1st R ₁	2nd radial	2r
2nd radial 2nd submarginal	2nd radial	2nd R ₂	3rd radial	3r
Appendiculate	appendiculate	appendiculate	apical	ap
2nd cubital	2nd cubital	R ₃	1st median	1m
3rd cubital	3rd cubital	R ₁	2nd median	2m
4th cubital	4th cubital	R ₃	3rd median	3m
3rd submarginal	3rd radial	R ₂	4th median	4m
1st discoidal	1st discoidal	M ₁	1st submedian	1sm
2nd discoidal	2nd discoidal	1st M	2nd submedian	2sm
1st posterior	1st posterior	M ₁	3rd submedian	3sm
Subcostal		M	basimedian	bm
Median	median	Cu	basicubital	bcu
3rd discoidal	"	Cu ₁	1st cubital	1cu
	3rd discoidal	M ₃	2nd cubital	2cu
2nd posterior	2nd posterior	2nd M ₂	3rd cubital	3cu
Lanceolate (hind wing)	1st anal	1st A	1st subcubital	1scu
Lanceolate (fore wing)	1st anal	1st A	1st subcubital	2scu
Anal	2nd anal	2nd A	anal	a
	3rd anal	3rd A	subanal	sa

vidual cells are derived from the vein along the anterior margins of each, and they are therefore identical with vein names. The common names are somewhat variable, as shown in the list on page 25:

Abdomen — the third and usually the largest region of the body; composed of a series of similar segments variable in number, usually 11 in the more primitive forms. In the higher insects there are normally nine or 10 visible segments, but they may coalesce, telescope, or be reduced in numbers so that only three or four may be seen. The abdomen may be rigid in most beetles and weevils but is normally quite elastic, and the terminal segments, at least, are freely movable owing to their own resilience and to the thinner and more flexible texture of the connective tissues between them. The abdomen is broadly or narrowly attached to the thorax. In the latter case the first segment may be closely fused to the metathorax so as to become more a part of it than of the abdomen. This fused member, known as the *propodeum*, is common among many of the HYMENOPTERA. One or two segments following the propodeum may be extremely narrow and form a *pedicel*, while the remainder of the abdomen, which is more or less globular, triangular, or elongated, is called the *gaster*. This condition occurs among hymenopterous parasites, ants, and wasps. Certain flies have a more or less pedicellate abdomen but lack the *propodeum*.

On the venter of each of segments II to IX of *Machilis*, and VIII and IX of *Lepisma* in the THYSANURA and I to VII of *Iapyx* in APTERA is a pair of plates, the *coxites* or *coxosterna*, each of which bears a single small two-segmented finger-like *stylus*, also thought to be rudimentary abdominal legs. Smaller similar appendages occur on abdominal segments I to III in the PROTURA. The *prolegs* of larvæ are *pseudopods*: paired, unsegmented, short legs which are important organs of locomotion and attachment, varying in number from two to 10 pairs. In the caterpillars they are furnished with apical *crochets* or *claws* which are absent in the sawflies.

In the COLLEMBOLA there are two organs not found in other insects: the *cellophore* or *ventral tube*, a simple or bifid process with eversible sacs which exude a sticky fluid to help in adhering to objects, and the *spring*, a small but powerful two-segmented posterior forked appendage for leaping.

The posterior region of the abdomen is modified in many ways both as to the character of the terminal segments and of the appendages attached thereto. Some of these parts are: The *cercus* (pl. *cerci*) — a pair of simple or segmented, antennæ-like, tactile organs arising from the lateral posterior margins of segments X or XI; extremely long in mayflies; modified into a pair of pincers in earwigs and japygids. The *cercoids* — cerci-like appendages arising from segments IX or X of larvæ, are "of a problematical nature" according to Imms (1937). *Median caudal filament* — a long cercus-like tactile organ between the cerci in THYSANURA. *Pygidium* (pl. *pygidia*), *suranal plate* or *epiproct* — the last exposed abdominal tergite in beetles; the terminal unsegmented region in armored coccids. *Propygidium* — the tergite (VII) preceding the pygidium in beetles with short elytra (Dalla Torre).

Genitalia or *gonapophyses* — the genital organs on segments VIII and XI in females and IX in males. In the females they may be modified into an exerted or retractile *ovipositor* or egg-laying organ of extremely specialized nature and into a *sting* in the ants, wasps, and bees. Associated with the male genitalia may be the *claspers* (*harpé* in LEPIDOPTERA) or holding organs; the *ædeagus* or *penis*, the intromittent organ; and the *parameres* or outer valves. The *anus* or *anal opening* is located in various positions at the extremity of the body. *Abdominal spiracles* never exceed more than eight pairs in adult insects. The number may vary from none in some COCCIDÆ to eight pairs in certain HYMENOPTERA. A further discussion will be found under the orders.

Glandular openings of different kinds are to be found upon various parts of the bodies. *Sound-producing organs* of many types are associated with the body and its appendages. *Stridulating* or *rasping organs* occur in the ORTHOPTERA, HEMIPTERA, COLEOPTERA, HYMENOPTERA, and other orders. Sounds made by striking the body or one of its parts against an object are caused by certain members of CORRODENTIA, ISOPTERA, and COLEOPTERA. Vibrating sounds are produced by cicadas, and during flight by beetles, flies, butterflies, moths, bees, and many other flying insects.

INTERNAL ANATOMY

The study of the internal anatomy of insects has long been a somewhat neglected field in entomology although some very important contributions were made in the 18th and 19th centuries by the so-called minute anatomists, Lyonet (1760), Straus-Durckheim (1828), Dufour (1811–1863) and others. During the years that followed, many outstanding papers were published by Packard (1875–1880), Viallanes (1885–1893), Miall and Denny (1886), Heymons (1892–1901), Holmgren (1895–1916), Janet (1894–1911), and others during the latter part of the 19th century and by such modern authors as Crampton (1914–1923), Snodgrass (1921–1935), Bugnion (1921–1930), Weber (1924–1933), Wigglesworth (1929–1934), and many others. With an abundance of basic literature available, the student will have no difficulty in pursuing investigations not only in the morphology but also in the physiology of insects.

A general discussion of the exoskeleton has already been given. In viewing the internal systems it must be remembered that the insect body is a compact, elongated, and somewhat cylindrical organism, the exterior shell or exoskeleton of which is animated by the internal systems which have no means of attachment and support other than is afforded by its relatively thin walls. Yet the numerous organs within are arranged in a symmetrical order which maintains a truly definite pattern throughout the class. A cross section of the body would show the exoskeleton or body wall; a variable amount of muscular tissues attached to the whole inside of the body wall and motivating all the external appendages and internal organs which have to do with movement; the adipose or fat body, the respiratory or tracheal system located laterally; the digestive tract, silk glands, sexual organs disposed medially; the seat of the circulatory system situated dorsally; and the nervous system located ventrally.

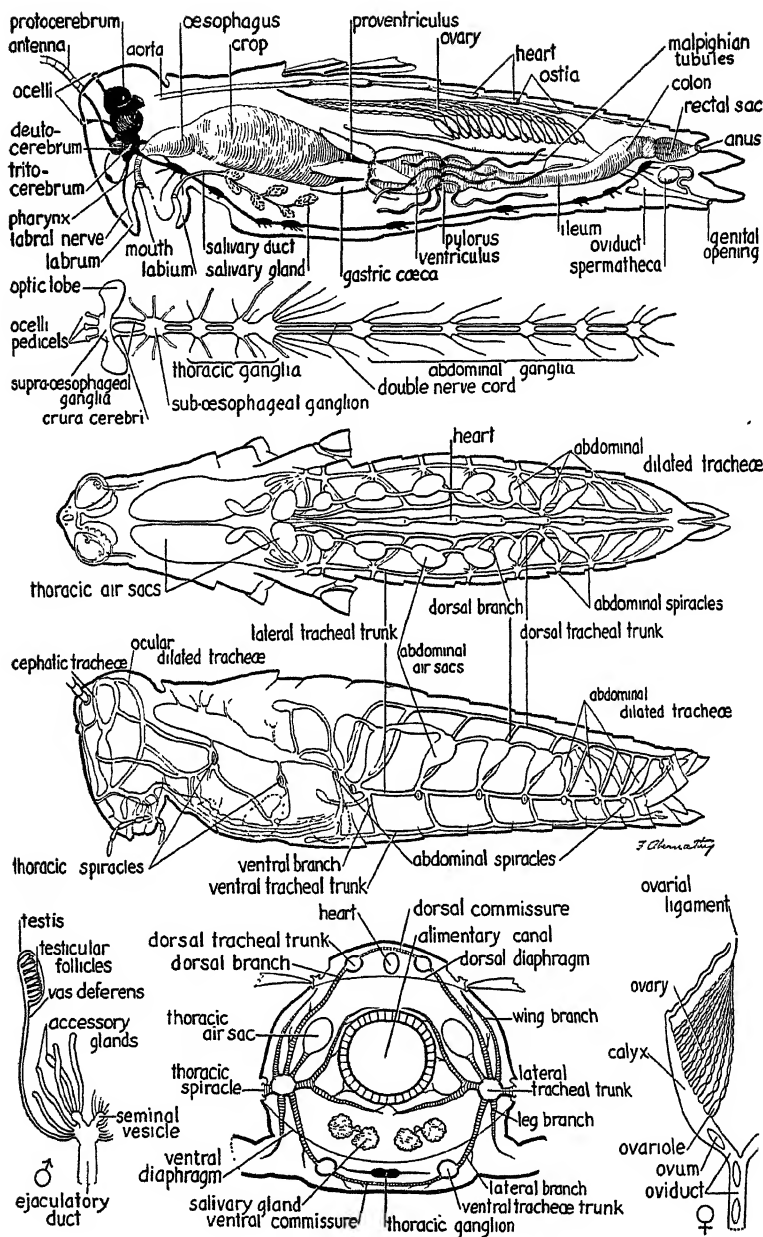


FIG. 13. Diagrammatic drawings showing some of the important internal systems of the grasshopper. (Original and modifications from Packard, Snodgrass, Weber, Michener, and Vinal.)

MUSCULAR SYSTEM

A considerable portion of the insect body is composed of muscular tissues which may almost completely occupy the head and thoracic cavities, serving as powerhouses for motivating especially the organs of ingestion and locomotion. The muscles are whitish, grayish, pale yellowish, or rarely pinkish in color and are distinctive in being cross-striated and therefore easily distinguished from other body tissues. They are grouped in flat or strap-like fibers or bundles which act as small or large units. In the thoracic regions of winged insects the muscles may be massed in compact lobes. The number of distinct muscles is very great. Lyonet, in studying the European goat moth, distinguished 4,041 separate muscles which he figured with great care. The *skeletal muscles* are mostly elongated, parallel fibers attached to or united with the cuticle by minute *tonofibrillæ* or *cuticular fibrils*. Certain groups of fibers may converge into tendons at points of insertion at the apodemes. *Visceral muscles* may be longitudinal, circular, or arranged in a network of branching fibers.

Appendages are usually operated by two sets of muscles, the *abductor muscles* that open out or extend an appendage away from its base, and the *adductor muscles* which pull or draw the appendage towards the base. The wings are moved by the *anterior* and *posterior pleural muscles* operating on the sclerites to which the bases of the wings are attached. These large muscles are only slightly elongated in pulling the sclerites and vibrate with great rapidity to enable swift and almost tireless flight.

FAT BODY OR ADIPOSE TISSUE

Under the layer of muscular tissues and more or less surrounding the other systems lies the fat body or adipose tissue, a definite system derived from the mesoderm, which is composed of large loose or tightly compressed cells which are whitish, yellowish, orange, or greenish in color. It is composed not only of fats but also of proteins and glycogen and constitutes the stored-up food reserves. It may be present in the larval, pupal, and adult stages. This food material is liberated into the blood and is available at any time in the growth of the larvæ and histogenesis of the pupæ and during the life of the adult. In the larvæ it is often very extensive, especially in caterpillars, maggots, grubs, and the larvæ of hymenopterous forms of all kinds. In the immature forms of insects that are without Malpighian tubules the fat body may act as organs of secretion and become loaded with urates. This condition may also occur in certain fly pupæ and in the larvæ and pupæ of insects with complete transformations, in which case the urates finally discharge into the alimentary canal upon transformation into the adult condition. Some of the fat body may be transferred to the adults or may be stored after maturity has been attained. It may then provide food reserves for hibernation or for egg production in the females.

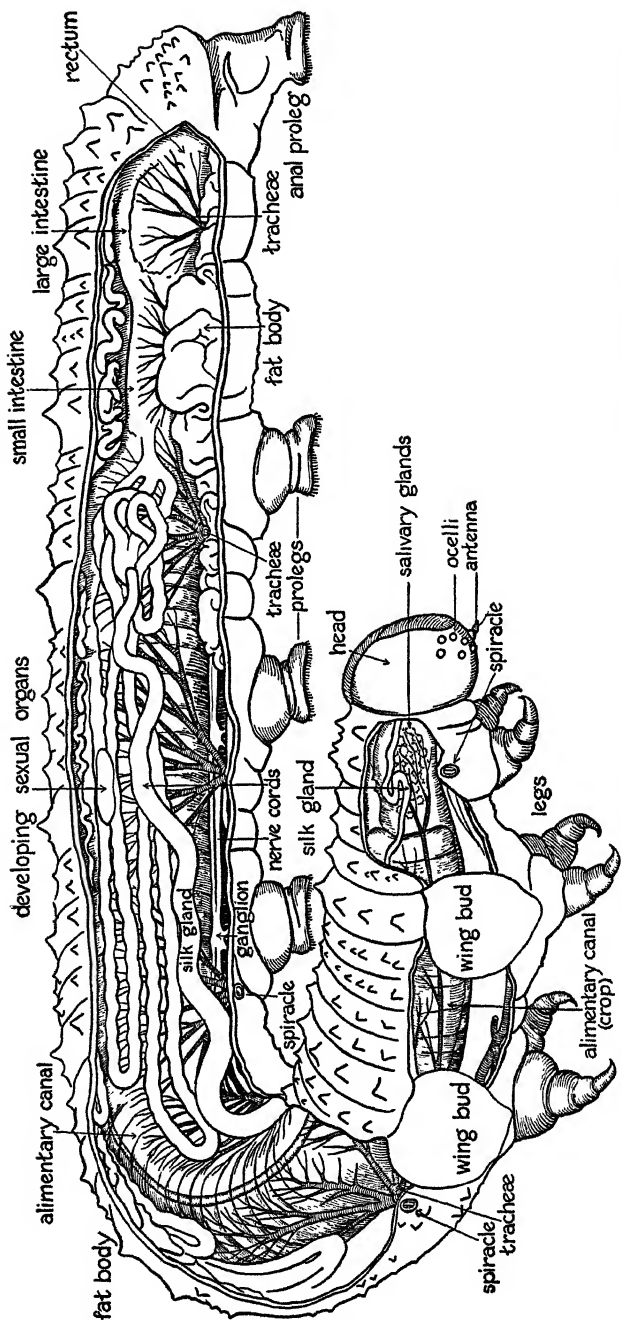


FIG. 14. Important internal systems of the caterpillar of the European cabbage butterfly, *Pieris brassicae* (Linn.). (After Pfurtscheller.)

DIGESTIVE SYSTEM

The digestive system, including the alimentary canal and its appendages, lies centrally throughout the length of the body and may be more or less straight and little longer than the body in larval forms or convoluted and otherwise modified and considerably longer than the body in adults. It is subject to considerable variation in particular organs and especially so in the herbivorous members of the class. The important organs are discussed in their order, beginning with the mouth.

Mouth or buccal cavity — beginning of the alimentary canal; variable in size; salivary glands empty at base of hypopharynx.

Stomodæum, fore intestine, fore gut.

Pharynx — cavity of variable size between the mouth and œsophagus; upper end of the stomodæum; muscular area; organ of ingestion.

Œsophagus — usually a straight, narrow, constricted tube located in the neck region of the head and fore part of the thorax; walls may be folded.

Crop or food reservoir — varies from a tube to a greatly enlarged sac which may be the most conspicuous part of the alimentary tract in certain herbivorous orthopterous insects; small in predacious and nectar-gathering species; the region of digestion.

Proventriculus or gizzard — a relatively small sac; the terminal part of the fore intestine; well developed in mandibulate, herbivorous insects; a powerful, muscular, grinding and mixing organ; the inner lining is furnished with muscular folds, chitinized ridges, teeth, spines, and other grinding surfaces.

Œsophageal, stomodæal, or cardiac valve — a fold or invagination of the fore intestine into the mid-intestine; may be simple or complex.

Filter chamber — a more or less complicated coil or loop involving the union or fusion of the œsophagus and the mesenteron, the œsophagus and proctodeum, or the mesenteron and the proctodeum; present in most but not all of the HOMOPTERA and is thought to short-circuit the excess liquid food and to pass it on directly to the posterior region of the alimentary canal.

Mesenteron, mid-intestine, mid-gut, ventriculus, stomach.

The middle region of the alimentary canal; complex in many insects; lined by the *peritrophic membrane* which surrounds the food.

Cardia — an enlargement of the anterior portion of the mesenteron in DIPTERA.

Gastric cæca, enteric cæca — sac-like protrusions.

Proctodeum, hind intestine, hind gut.

The posterior region of absorption; with a number of complex structures.

Anterior intestine or pylorus — the forward region connecting with the mesenteron, often with a valvular fold or *pyloric valve*.

Malpighian tubules, Malpighian tubes, Malpighian vessels (named by Meckel in 1829 for their discoverer, M. Malpighi, who first reported them in

1669) — tubules arising from the pyloric region; consisting of two, four, or six pairs¹ which may divide into innumerable smaller branches up to 150 or more; variable in length, sometimes longer than the body; straight or coiled; closed apically; may have basal valves; in some chrysomelid beetles (*Galerucella* and *Altica*) two anterior tubes discharge into the mesenteron and the four posterior tubes open into the proctodeum (Wigglesworth). They are urinary in function in most insects but act as silk glands in some of curculionids (*Hypera* and *Phytomus*).

Ileum — the anterior tube-like portion, and the *colon*, the posterior enlarged part, of the anterior portion of the hind intestine.

Posterior intestine — the enlarged terminal portion of the alimentary canal. Its dilated anterior part, the fermentation chamber, is the *rectal sac*, and the narrow tubular or somewhat enlarged apical portion is the *rectum* which empties through the *anus*. The *rectal cæcum* is a pouch formed by the blind end of the *rectal sac* when the anterior intestine connects on the side of that organ. *Rectal glands* or *rectal papillæ* may occur as large cells of variable size and form which may be disposed in symmetrical order in nearly all orders of insects except the HEMIPTERA, whose members consume quantities of liquid foods. In the beetles and weevils the number and arrangement of these papillæ may be of taxonomic value. A *peritrophic membrane* is present in the orders ISOPTERA, ORTHOPTERA, COLEOPTERA, LEPIDOPTERA, and others that pass dry pellets.

CIRCULATORY SYSTEM

The motivating organ of this system is located dorsally along the median longitudinal line. It is for the most part an open system and has little in common with the closed circulatory systems of higher vertebrate animals. The *heart* or *dorsal tube* is the *pulsating organ* and consists of a long, cylindrical or somewhat flattened, elastic, rarely chambered tube lying along the dorsum of the abdomen. It is closed posteriorly by valves which, with the *ostia* or slit-like valvular openings along the sides, admit the blood from the body cavity and close so as to send it forward by pulsations due to the waves of body contractions into the *aorta*, or that portion of the heart passing through the thorax and into the head, where it is discharged in the region of the œsophageal ganglia. From this point the blood is forced into the appendages and to all parts of the body and is taken up again by the heart and pumped forward in rhythmic pulsations. The *blood* of insects, except in a very few cases noted below, is without *hæmoglobin* or red coloring matter. It is composed of *plasma* and of *leucocytes* or colorless corpuscles, similar to those in vertebrate animals, and appears yellowish or greenish in color. It fills the body cavity, bathes all of the tissues freely, collects beneficial and waste materials from the digestive system,

¹Orders of insects with few Malpighian tubules are said to be *oligonephric* and those with many, *polynephric* (Tillyard, 1926).

glands, and other organs, and distributes the beneficial products where needed while the waste material is given up to the Malpighian tubules. It is rather remarkable that red blood occurs in the blood gills of certain aquatic insects: the larvæ of a few caddisflies, midges, buffalo gnats or black flies, beetles, and caterpillars.

RESPIRATORY SYSTEM

The breathing or respiratory system is closed, and its elastic *tracheæ* or tubes and *tracheoles* or tubelets resemble the general plan of the arteries, veins, and

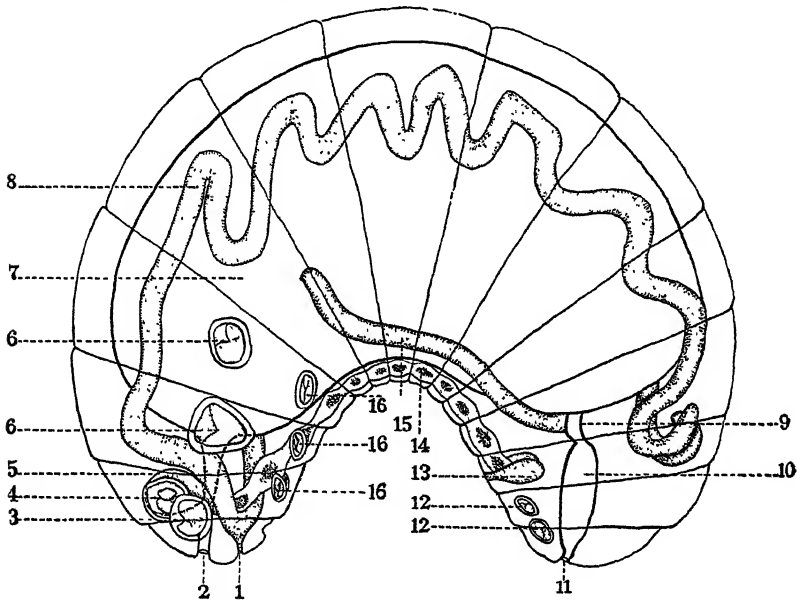


FIG. 15. Mature larva of *Incubus ribis* (Haliday) showing important external and internal characters. 1, orifice of silk gland; 2, mouth; 3, imaginal disc of eye; 4, imaginal disc of antenna; 5, supracæsophageal ganglion; 6, imaginal discs of wings; 7, stomach; 8, silk gland; 9, ihum; 10, rectum; 11, anus; 12, imaginal discs of genitalia; 13, gonad; 14, nervous system; 15, malpighian tubule; 16, imaginal discs of legs. (After E. W. Wheeler, 1923.)

capillaries of the closed circulatory system of vertebrate animals. In a sense the system functions similarly in that it aërates the tissues of the body. It consists of large hollow tubes or *tracheæ* which branch, anastomose, and increase in numbers as they are reduced in size. The smallest units or *tracheoles* are microscopically minute, capillary-like tubelets of uniform dimensions which arise independently of and anastomose with the tips of the *tracheæ* to connect the system and to aid in the transmission of oxygen to all organs of the body. The lining of the *tracheæ* is composed of three layers: the *intima*, a chitinous inner lining which is a continuation of the outer body wall with spiral thread-

like thickenings or *tænidia* giving a striated appearance and which in some insects may be unwound like a spring and, like the exterior layer of the integument, is shed with each molt; the *epithelium* or cellular outer layer arising from the body membrane; and the *basement membrane*, the delicate outer layer supporting the epithelium.

Air sacs of different sizes, formed by dilations of the tracheæ, may occur in grasshoppers, flies, and bees; and almost the entire abdomen of cicadas may constitute an air reservoir. *Spiracles* or *stigmata* are the openings of the tracheæ. They are elongated or circular apertures, each supported by a *peritreme* or small annular sclerite, and may have simple and fixed openings or highly specialized and adjustable ones. The latter may be with or without lips; with or without a chamber or *atrium* near the entrance; with a number of opening and closing devices such as bands, lips, and other types of valves; and with a variable number of openings or pores to each spiracle as in the larvæ of some DIPTERA. In adult insects they occur as paired organs along the sides of the thorax and abdomen and may vary in number from two pairs in the COCCIDÆ to 11 pairs in the IAPYGIDÆ. The usual number is 10 pairs, two thoracic and eight abdominal. In the larvæ the number may vary from two pairs in the newly born up to 10 pairs in the full-grown forms. The position of the spiracles in larvæ may vary considerably, as is noted elsewhere in the text.

Aquatic insects breathe by means of tracheal gills which may arise, in the normal position of the spiracles, from the sides of the bodies in mayflies and other groups, from the rectal cavity in dragonflies, and as anal gills in damselflies. *Blood gills*, already noted, are present in a few aquatic insects in the orders TRICHOPTERA, DIPTERA, COLEOPTERA, and LEPIDOPTERA. Certain aquatic insects have special modifications of the body for carrying air under water. They thus provide oxygen during their submersion, replenishing the air by returning to the surface for a fresh supply. Others have respiratory tubes for obtaining air by puncturing the cells of aquatic plants (in certain male mosquitoes) or by permitting the apical portion of the tube to extend above the surface of the water (larvæ of the drone fly).

The following types of respiratory systems are recognized among insects:

- I. **Holopneustic** — all of the spiracles open; normally two thoracic and eight abdominal pairs. In adults of most orders and in larvæ of many.
 1. *Hyperpneustic* — all of the spiracles open and with three or four pairs on the thorax in a few THYSANURA instead of the usual two.
- II. **Hemipneustic** — one or more pairs of spiracles closed.
 1. *Amphipneustic* — prothoracic and posterior abdominal spiracles open. In larvæ of DIPTERA.
 2. *Metapneustic* — only the last pair of spiracles open. In larval stages of most DIPTERA and aquatic COLEOPTERA.
 3. *Peripneustic* — usually with only a few pairs of spiracles closed along the sides of the body. In NEUROPTERA, MECOPTERA, and a few DIPTERA, COLEOPTERA, LEPIDOPTERA, and phytophagous HYMENOPTERA.

4. *Polypneustic* — with at least three pairs of functional spiracles. In DIPTERA and other orders.
 5. *Propneustic* — only the first pair or prothoracic spiracles open. In the pupæ of CULICIDÆ.
- III. *Apneustic* — spiracles wanting. In CHAOBORIDÆ and in first larval stages of some parasitic HYMENOPTERA.
1. *Branchiopneustic* — spiracles replaced by gills. In immature EPHEMERIDA, PLECOPTERA, ODONATA, aquatic NEUROPTERA, and a few aquatic DIPTERA.

NERVOUS SYSTEM

The principal organs of the nervous system are located ventrally along the median line and consist of a series of *ganglia* or nerve centers connected by a double nerve cord and radiating nerves and nerve fibers to all parts of the body. The *brain* or *supraesophageal ganglion* is located in the head above the œsophagus and innervates the antennæ, eyes, and labrum. The *mushroom bodies*, developed in ants and bees, are groups of cells whose fibers unite to form stalked nerve structures in the *protocerebrum*, or the larger part of the brain which controls the eyes and ocelli. The *subœsophageal ganglion*, situated below the œsophagus, innervates the mouth parts except the labrum. Two cords, the *crura cerebri*, one on each side of the œsophagus, connect the brain and the subœsophageal ganglion. The *thoracic ganglia* may consist of three separate nerve centers located in the different segments or they may be fused into one or two ganglia in some insects. The *abdominal ganglia* are normally distributed, one in each segment, or they may be fused into fewer centers. Wherever a ganglion is located in a segment, it becomes the nerve center of that particular part of the body.

SENSE ORGANS

The sense organs of insects are so numerous and varied as to require special study in the various orders, families, and genera. In general they consist of those having to do with feeling, sight, smell, taste, and hearing. *Tactile organs* are very important as protective devices of insects and are numerous and varied. The antennæ are among the most important. They are present in all orders except the PROTURA and are highly specialized in nearly every family. They are equipped with sense hairs, spines, and setæ which react to touch, and some insects respond very quickly to them. The cerci are similar structures that guard the rear. Hairs, spines, bristles, and appendages of various kinds, arising from the exoskeleton of larval and adult insects, may also function as organs of touch.

Eyes. — Sight is wholly absent or very poorly developed in certain few subterranean, light-shunning, and cave-dwelling insects and has evolved to a variable degree in other forms. Insects are either attracted to light and are *phototropic* or shun the light and are *negatively phototropic*. Forms that are ac-

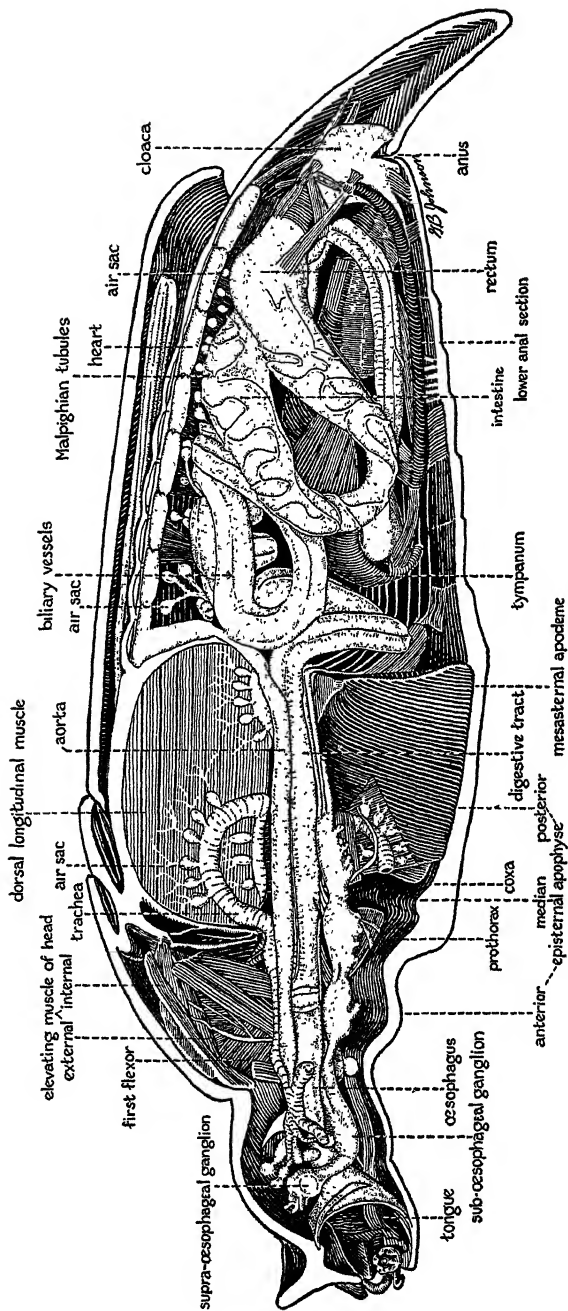


FIG. 16. Sagittal section of the European may beetle, *Melolontha melolontha* (Linn.), showing internal systems. (Drawing from a French model.)

tive during the day are said to be *diurnal*; those active in the evening and twilight, *crepuscular*; and those active at night, *nocturnal*. Most insects have two kinds of eyes: compound eyes and ocelli. *Compound eyes* — large and conspicuous eyes composed of a few or a large number of *facets*, *ommatidia*, or *sensillæ* which are tube-like and arranged in a series pointing towards a common inner center where the light falls upon the retina and is transformed into stimuli transmitted to the brain. A stationary object appearing in an eye-field that consists of hundreds or thousands of facets is thought to create a mosaic image, while a moving object passing across such a series of separate lenses is detected by setting up stimuli in each series of facets as it advances. The eyes are sometimes provided with a lateral tubercle (in most aphids) or may be divided transversely (in whirligig beetles) and rarely partly stalked (in a few mayflies [*Cloëon*]) and stalked (in a few DIPTERA). The facets may also vary in size in different parts of the same eye; and the whole may be greatly reduced in size and in numbers of facets in many insects. Compound eyes function to determine motion and react to color patterns and to light stimuli.

Ocelli (sing. *ocellus*) — simple, single lenses that are thought to be chiefly “stimulatory organs which accelerate phototaxis by increasing the sensitivity of the brain to light-stimuli received through the compound eyes” (Eltringham). They are thought to respond to light and may faintly discern objects in motion near at hand. Those of the adults are often classified as *primary*, *dorsal*, or *primitive ocelli* when three in number and are arranged in a triangle on the vertex and frons. The *median ocellus* is sometimes double in dragonflies and ants, indicating a primitive condition of two pairs. It occurs in nymphs and adult PTERYGOTA. *Adaptive* or *lateral ocelli*, frequently referred to as *ocellanæ* (sing. *ocellana*) and *stemmata* (sing. *stemma*), occur on the lateral sides of the head of larvæ. They vary in number from one in TENTHREDINIDÆ to a maximum of six or seven on a side in NEUROPTERA, COLEOPTERA, and LEPIDOPTERA. They are particularly well developed in the tiger beetles and enable these active larvæ to capture living prey.

Organs of smell — exceedingly variable. The best developed ones appear to be the *sensoria* on the antennæ of aphids and other HOMOPTERA and the *sensilla* on the antennæ of most insects. These consist of innervated oval or circular pits covered by a flat or convex membrane. In aphids they are most numerous on the antennæ of winged individuals and are especially abundant in males, whether alate or apterous. A few occur on the wingless parthenogenetic females. On the hind tibiæ of the sexual female aphids are sensoria-like organs which may function as organs of smell. The *sensillæ* of the higher orders may occur in very great numbers on the antennæ of certain beetles, moths, bees, and other insects. Organs of smell also occur on the palpi which are furnished with *sensilla*. *Sensilla* with setæ or cones may arise from the antennæ, palpi, or the body cuticle.

Organs of taste — occur in connection with the mouth parts, pharynx, antennæ, tarsi, and other parts of the body and are structures similar to those of smell.

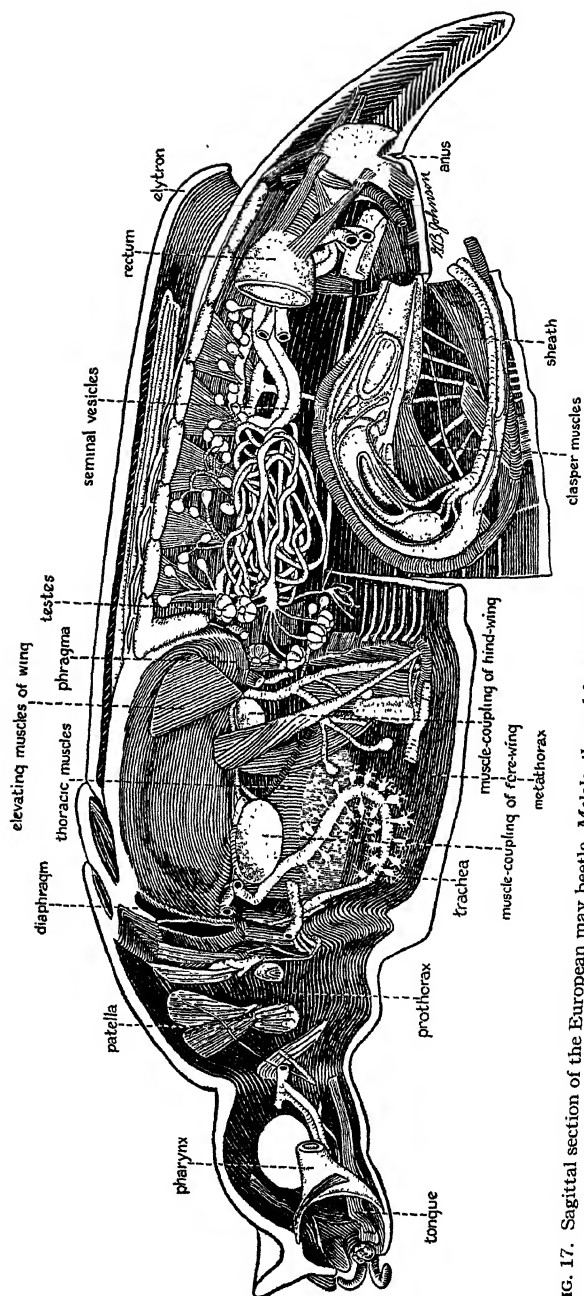


FIG. 17. Sagittal section of the European may beetle, *Melolontha melolontha* (Linn.), similar to that shown in Fig. 16 with certain organs removed to show other structures.

Organs of sound and hearing. — It is generally supposed that insects capable of producing sound are also able to hear. Organs of sound have previously been discussed in the chapter on external anatomy and consist of many kinds of stridulating organs, flight mechanisms, tympanums or drums, and other devices. The *chordotonal organs* are variable complex structures which are sound receptors or tension receptors and according to Snodgrass (1935) are cellular elements with or without *scolops* or *sense rods* which constitute elongated structures both of whose ends are attached to the cuticle. *Johnston's organ*, first observed by Christopher Johnston in 1855, is a specialized cup-like chordotonal organ occupying much of the second antennal segment in DIPTERA, being especially well developed in hairy antennæ of male mosquitoes and midges and, to a lesser degree, of bluebottle and greenbottle flies; in LEPIDOPTERA in satyrid butterflies, and in HYMENOPTERA in paper wasps (Imms). The *tympanal auditory organs* on each side of abdominal segment I of grasshoppers, and on the fore tibizæ of crickets and katydids, are highly specialized structures known as the "ears" of these insects.

GLANDULAR SYSTEM

The many variable and important glandular organs of insects are not closely enough coördinated to constitute a "system" in the real sense of the word, so this term is used in a very general sense to denote a grouping of miscellaneous glandular organs of similar structures and functions.

Salivary glands — a variable number located in the head and thoracic regions which open by means of one to four or more pairs of ducts at the base of the hypopharynx of adult and larval forms.

The *frontal gland* of the nasute termite exudes a sticky fluid used as a defensive and offensive weapon against enemies.

Molting glands — numerous minute unicellular bodies, secreting fluids necessary for the shedding of the skin during the process of molting in insects exposed to air, light, and heat.

Silk glands — often a pair of very large tubes, occupying much of the body cavities of lepidopterous larvæ. The silk is drawn through a single spinneret on the labium. The *glands of Filippi* are associated with the *silk press* at the posterior region of the mouth. In embiids, silk glands and a series of spinnerets occur in the enlarged first tarsal segment. In certain curculionid and neuropteroid larvæ silk is produced by the Malpighian tubules, obtained from the anus by means of the mouth parts, and used to construct lace-like cocoons or for other purposes. The *glands of Batelli* are hypodermal glands opening into the rectum and secreting a fluid which is forced from the anus along with air bubbles to form the froth or spittle of spittle bugs.

Setal glands are very numerous in the larvæ and adults of many insects. They are small glands with outlets through *lumina* or tubes of *setæ* or "*tenant hairs*." The venomous stinging and poisonous hairs of certain "woolly" caterpillars are of this type. *Tenant hairs* that secrete sticky fluids also occur on the

pulvilli or empodia as an aid to ceiling- and floor-walking flies and other insects.

Odorous glands of various kinds occur in a large number of insects. The scent glands of female moths, which surely would seem to be present, have not been located (Wigglesworth 1939). *Androconia*, or specialized glandular scales, occur on the wings of male butterflies. Their odors are thought to attract the females. The *osmeteria* or *forked glands* of the larvæ of swallowtail butterflies are conspicuous forked or horn-like organs protrusible from an invagination of the hypodermis in the dorsal apex of the prothorax. When exposed, they emit a strong pungent odor thought to repel birds and other natural enemies. Other types of scent glands also occur on abdominal segments VII and VIII in caterpillars of gossamer-winged butterflies. *Stink glands* are especially offensive in shield bugs and pentatomid bugs, where they occur as a pair on the sternites near the middle coxæ, and in the bedbug, where they consist of three pairs on the tergites of abdominal segments I to III inclusive. The anal stink glands of beetles are among the most powerful in the insect world. A single specimen of the Pacific coast malodorous carabid, *Nomius pygmaeus* (Dejean), a very small black beetle, emits an odor so offensive as to cause sickness and to quickly empty a school-room, as many a country school teacher knows. The bombardier beetle, *Brachinus tschernikhi* Mannerheim, expels offensive volatile liquids in a series of audible explosions, as do staphylinid and other beetles. The odors of carabid and of darkling ground beetles are well known to collectors everywhere. In fact, there are few insects that do not secrete protective fluids.

Wax glands are present in many insects and notably among the members of the suborder HOMOPTERA and the honeybees.

PROTECTIVE DEVICES

The fact that insects have survived millions of years without being greatly altered in size and form or reduced in numbers testifies to their fitness to meet the varied conditions of this earth to such an extent as to exceed all other forms of life in numbers of species. This fitness is no doubt due in great part to their inherent physiological structures and remarkable life histories. Although insects react to the stimuli caused by motion, they do not appear to be subject to fright. The aphid walks over the syrphid fly larvæ without hesitation; young scales crawl over the bodies of ladybird beetles; the pestiferous fly returns again and again, never seeming to tire; a mosquito is persistent to the end; no living thing ever frightened away a mad hornet or bee. That they are especially endowed with certain means of protection is more than evident, and a summary of some of these may serve to emphasize the many factors involved.

Body structures

Hard, elastic, or tough exoskeleton and elytra.

Resistance to corrosive chemicals.

Spines, rugosities, hairs, scales.

Rejuvenation of appendages (in lower or primitive adult and in larval forms).

Deciduous appendages (legs, wings, antennæ, cerci).

Protective coloration

Cryptic — green, gray, brown, and combinations to match the immediate background.

Mimicry — resemblance to other insects in color patterns; or with very bright and conspicuous warning colors.

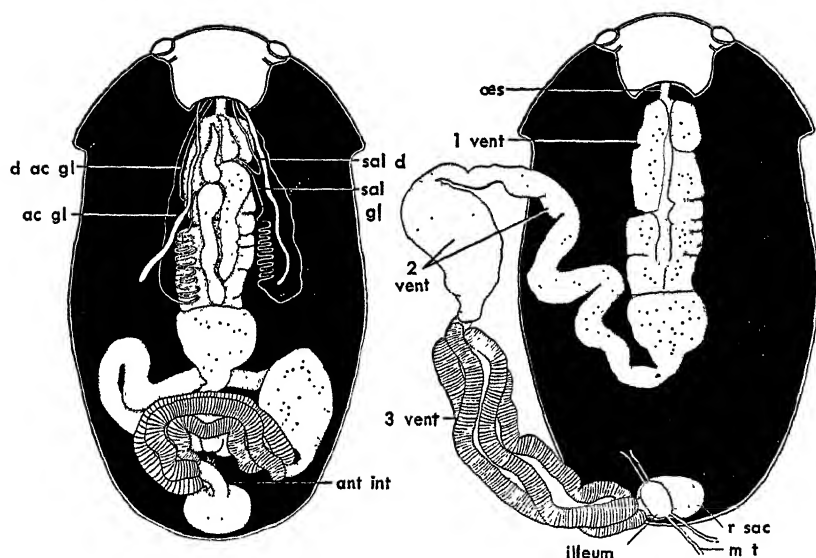


FIG. 18. Digestive and salivary systems of the harlequin cabbage bug, *Murgantia histrionica* (Hahn). ac gl, accessory salivary gland; ant int, interior stomach of the pylorus; d ac gl, duct of the accessory salivary gland; m t, malpighian tubule; oes, oesophagus; r sac, rectal sac; sal d, salivary duct; sal gl, principal salivary gland; 1 vent, first ventriculus or stomach; 2 vent, second ventriculus; 3 vent, third ventriculus with four rows of cæca. (After Harris, 1938.)

Special protective coverings and other devices

Wax and resin exudations, offensive glandular materials, poisonous body fluids and gases, stinging hairs.

Specially constructed devices

Burrows in wood, soil, debris; cases, cells in wood, earth, wax, paper, and shields; covering of fecal materials and debris; webs; cocoons; spittle; nests, formicaria, termitaria, paper nests, galls, seeds.

Methods of escape

Keen sight to detect motion, feigning death, hiding, burrowing, running, jumping, snapping, swimming, diving, flying; nocturnal, crepuscular, diurnal, seasonal habits.

Scaring or bluffing devices

Grotesque forms; bright colors and markings; greatly enlarged appendages; sounds: stridulating, buzzing, drumming.

Defensive weapons

Stinging hairs, setæ, spines; offensive fluids; strong jaws; strong crushing and kicking legs; ovipositor, sting, camouflaging.

Offensive weapons

Volatile fluids, sticky secretions, mandibles, sting.

REPRODUCTIVE SYSTEM AND REPRODUCTION IN INSECTS

Sexuality in insects is one of those subjects that may be pursued indefinitely without ever knowing all of the facts and details that are concerned with the most fundamental part of all life — that of reproduction. The ancient idea that insects originated spontaneously or by some “vivifying principle” was dispelled in part by Francis Redi in 1668, but even to this day thousands of supposedly educated human beings know little or nothing about how these small animals are able to maintain themselves continuously in such great numbers.

The early investigations of Hooke (1637–1703), Malpighi (1628–1694), Swammerdam (1637–1680), and Leeuwenhoek (1632–1723), with the aid of the microscope, revealed that insects were perfect animals with all of the possibilities of life and development of larger animals, but with many peculiarities until then wholly unknown and unsuspected. The veil of obscurity partly lifted by these “minute anatomists” was drawn much further back by the researches of Redi (1626–1698), Frisch (1666–1743), Réaumur (1683–1758), Bonnet (1707–1789), Roesel von Rosenhof (1705–1759), Linnæus (1707–1778), and a host of other almost equally competent students in many parts of Europe. It is remarkable how rapidly the intricacies of insect life were unraveled and exposed to the view of a curious but unappreciative world.

Practically all of the exact information we now have about these multitudinous and partly beneficial, mostly pestiferous and destructive, insects has been accumulated within the past three centuries. Knowledge has advanced to the greatest degrees along systematic and bionomic lines, and while considerable information has been accumulated relating to anatomy and physiology, much remains to be accomplished before we can compare that knowledge with achievements in the study of man and the higher animals. At the present time very great interest is manifested in these intricate and obscure problems relating to the inner life and reactions of insects as individuals and as members of the great scheme of nature. One of these important phenomena, reproduction, is probably as little known as any of the natural processes of this gigantic group of minutæ.

Owing to lack of space it is inadvisable to attempt to trace the origin of accumulated knowledge relating to the sexuality of insects, nor is it possible even to tabulate the many ramifications and particulars that enter into a discussion of any of the many phases of this subject.

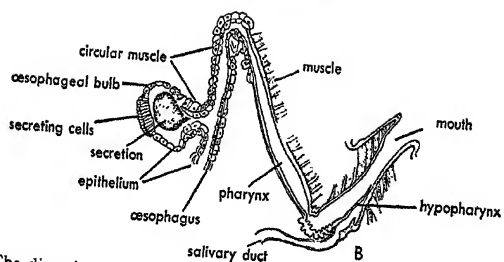
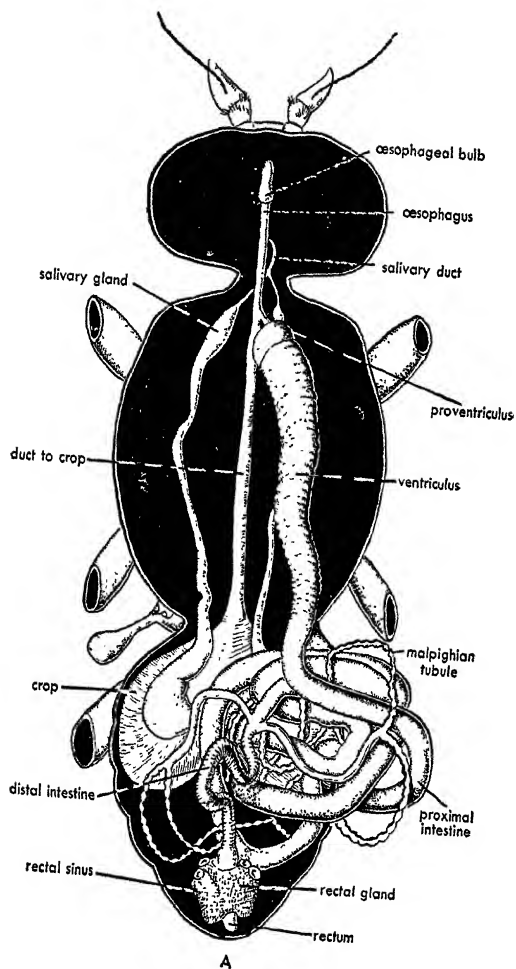


FIG. 19. The digestive system of the apple maggot fly, *Rhagoletis pomonella* (Walsh). A, gross dissection; B, sagittal section through the pharynx and esophagus. (After Dean, 1933.)

With certain notable exceptions, insects are for the most part unisexual, there being corresponding numbers of males and females in each species. Certain primary peculiarities, such as size, color, vestiture, and activity, may serve to distinguish the different sexes, and there are also innumerable external variations commonly known as secondary sexual characters that may modify almost every part of the body and readily serve to separate the males and females in what appears to the untrained eye to be a mass of identical individuals known as a species. On the other hand, sexual variations are sometimes so marked that

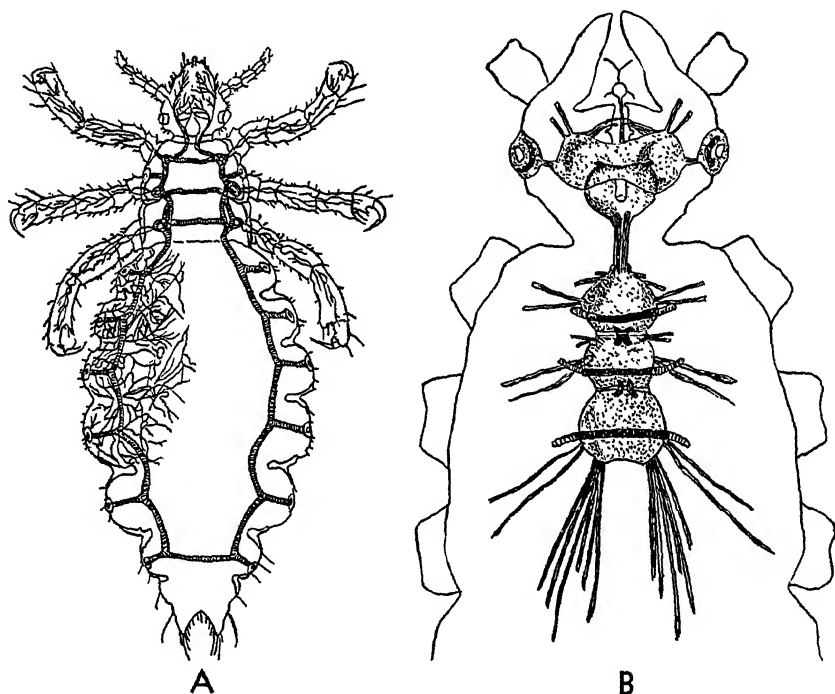


FIG. 20. The human louse, *Pediculus humanus* Linn. A, a portion of the respiratory system; B, the chief nerve centers or ganglia. (After J. Muller.)

males and females of the same species have frequently been relegated to different genera.

Certain insects have a sexual cycle followed by cycles of reproduction without mating (parthenogenesis), and a considerable number reproduce continuously by the latter method. In fact, in many species of aphids, weevils, and other insects, no males have ever been observed though these particular forms have endured for thousands and perhaps millions of years.

Suppressed sexuality is exhibited by certain individuals of a large number of species of insects, particularly those which have a form of social life like the termites, ants, bees, and wasps. In such insects the sexual organs, though

present, are not sufficiently developed to permit reproduction, and the individuals thus arising, whether of one or both sexes, are referred to as neuters or workers. Such sex suppression is not necessarily permanent, since whenever sexual reproductives are needed to perpetuate the colony in certain insects they may be derived from the neuter caste by a process peculiar to the species involved. In these insects the sexual females are relatively few in number, but have enormous reproductive capacities.

Gynandromorphism, while comparatively rare among insects as a whole, does occur regularly among certain members of such widely separated orders as the PLECOPTERA (stoneflies), HOMOPTERA (scale insects), LEPIDOPTERA (moths and butterflies), and HYMENOPTERA (bees). It is mani-

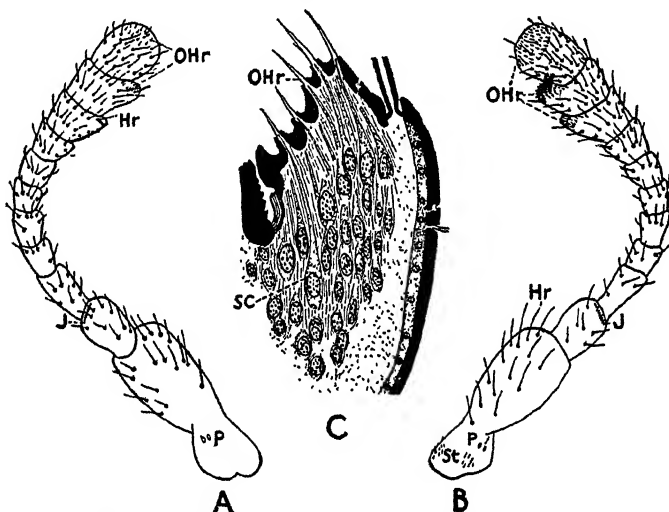


FIG. 21. Drawings of antennae of adult Mexican bean beetle, *Epilachna corrupta* Mulsant, showing sense organs on them. A, ventral surface, and B, dorsal surface, showing location of following: Hr, noninnervated hairs; J, Johnston's organs; P, pores called olfactory by McIndoo; OHr, so-called olfactory hairs; and St, tactile hairs. C, a semi-diagrammatic drawing from a section through the tenth segment, showing structure of so-called olfactory hairs (OHr) and their sense cells (SC). A and B, X 53; and C, X 500. (After McIndoo, 1931.)

fest by the presence in an individual of certain characters belonging to both sexes. One side of the body may have the external characters of the male and the other side those of the female. These characters may also be more or less evenly distributed in mosaic types, or those of one sex may predominate.

Among the true unisexual forms copulation usually takes place in a normal manner, but there are also some unique ways to transfer the spermatozoa from the male to the female as exemplified by the dragonflies and damselflies in which the sperm is first transferred from the posterior genital opening to the intromittent organ located on the venter of the second abdominal segment, a peculiarity found in no other order of insects. Other examples are given in connection with the discussions of the orders.

SEXUAL ORGANS

The reproductive organs of both sexes are similar in the early embryonic condition and are differentiated in the later stages of development. They are located latero-dorsally beneath the heart and occupy, with the digestive tract, much of the abdominal cavity. Following the arrangement of Imms (1934), "the sexual organs, and their counterparts in the male and female, may be tabulated" as follows:

<i>Male Organs</i>	<i>Female Organs</i>
1. Gonads: Paired testes composed of follicles (testicular tubes). Of many types and divided into four zones.	Gonads: Paired ovaries composed of ovarioles (ovarian tubes) (1) Panoistic (2) Polytrophic (3) Teletrophic or acrotrophic.
2. Gonoducts or genital ducts: Paired vasa deferentia (sperm reservoir).	Gonoducts or genital ducts: Paired oviducts (egg ducts).
3. Vesiculæ seminales (sperm reservoir).	Egg-calyces.
4. Ejaculatory duct (median in position).	Vagina (median in position).
5. Accessory glands: (1) Mesadenia. (2) Ectadenia.	Accessory glands: Colleterial (sebific glands).
6.	Spermatheca (sperm pouch). Bursa copulatrix (copulatory pouch).
7. Genitalia: Penis and accessory appendages.	Genitalia: Ovipositor and accessory appendages.

FEMALE REPRODUCTIVE ORGANS

Ovaries — organs that produce the reproductive cells. They are generally paired, although one may be aborted or the two may join cephalad to form a ring. They consist of a pair of somewhat compact bodies on either side of the alimentary canal and produce the mature germ cells, ova, or eggs. They are composed of a variable number of ovarioles, ovarian tubes, or egg tubes which are elongated tubes in each of which the developing oöcytes are produced in a single chain, the oldest being the ones farthest advanced down the ducts. The following types of ovarioles are recognized:

- (1) *Panoistic* — the primitive condition in which the nutritive cells are wanting and the oöcytes occur without interruption throughout the length of the oviducts, each surrounded by a mass of yolk and a membrane as it advances outward. This condition has been observed in

the APTERA (Iapyx), ISOPTERA, ORTHOPTERA, ODONATA, and SIPHONAPTERA.

- (2) *Polytrophic* — in which the nutritive or yolk cells alternate with the oöcytes. They may be grouped in chambers separated alternately by constrictions in some NEUROPTERA, COLEOPTERA (Adephagous), and HYMENOPTERA, or they may occur alternately without such dividing constrictions, as in LEPIDOPTERA and DIPTERA.
- (3) *Telotrophic or acrotrophic* — in which the nutritive cells are crowded at the upper apices of the ovarioles, as in HEMIPTERA and COLEOPTERA (Phytophagous), or combine to supply nourishment to each oöcyte by means of fine protoplasmic tubules from the nutritive chamber to the ova.

The zones or regions recognizable in the ovarioles are as follows:

- (1) *Terminal filament* — the filamentous apical prolongation of the ovariole wall. All the filaments of the ovarioles in the ovary combine into a single thread and those of both ovaries sometimes unite into the common median ovarian ligament which aids in supporting the ovaries in the body cavity. The ovarian ligament is not present in all insects.
- (2) *Germarium* — the apex of the ovariole below the filamentous prolongation which consists of a mass of cells from which the primordial germ cells and, in many insects, also the nutritive cells are differentiated.
- (3) *Vitellarium* — the major portion of the ovariole which encloses the developing oöcytes and the nutritive epithelial layer of the wall invaginates so as to surround each in a definite chamber or follicle. The cells of the latter secrete the chorion of the ova and may also nourish the oöcytes. Ovarioles, except as primitive follicles, are wanting in the

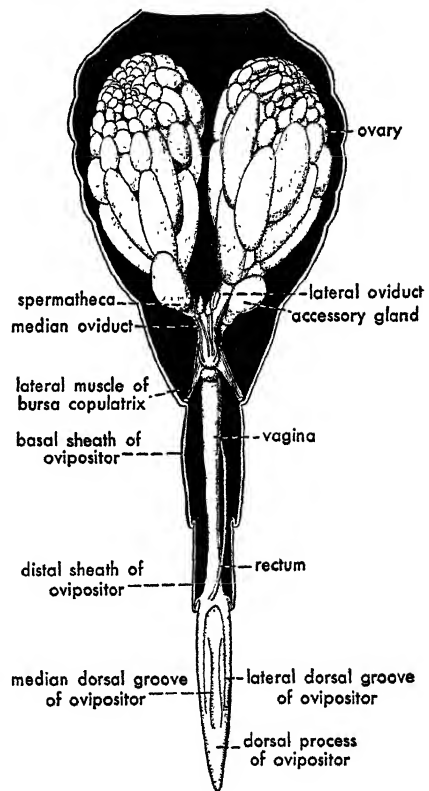


FIG. 22. The female reproductive system of the apple maggot fly, *Rhagoletis pomonella* (Walsh). (After Dean, 1933.)

oöcytes and the nutritive epithelial layer of the wall invaginates so as to surround each in a definite chamber or follicle. The cells of the latter secrete the chorion of the ova and may also nourish the oöcytes. Ovarioles, except as primitive follicles, are wanting in the

COLLEMBOLA and certain DIPTERA (*Chironomus*, *Anopheles*) and HYMENOPTERA (*Incubus*, in which follicles are present). The primitive number of ovarioles in each ovary does not appear to exceed eight (in *Periplaneta*), but the number is exceedingly variable as the following tabulation will show (Imms, 1934):

- 1 ovariole in each ovary of viviparous DIPTERA (*Glossina* and *Termitoxenia*).
- 2 ovarioles in each ovary in certain DIPTERA (*Melophagus* and *Hippobosca*), COLEOPTERA, and HYMENOPTERA.
- 4 ovarioles in each ovary common among the LEPIDOPTERA.
- 5-7 ovarioles in each ovary in certain ORTHOPTERA (*Periplaneta*).
- 100 or more ovarioles in each ovary in certain DIPTERA (*Calliphora* and *Hypoderma*).
- 200 or more ovarioles in each ovary in certain HYMENOPTERA (some ants) and COLEOPTERA (*Meloe*).
- 2,400 or more ovarioles in each ovary in some ISOPTERA (*Termes*).

In certain of the sexual females of HOMOPTERA, especially in the plant lice (APHIDIDÆ and PHYLLOXERIDÆ), there is but one fully developed ovary, the other being atrophied.

Oviducts. — In the female the paired oviducts or canals consist of an epithelial layer of mesodermal origin leading from the gonads to the point of the primitive gonopore or genital opening. In the EPHEMERIDA, which exhibit a primitive condition, there is a separate opening for each duct. In the THYSANURA, PLECOPTERA, and ODONATA they are united in a single cup-like invagination, but in most insects they unite to form a common duct before reaching the exterior. This common duct or vagina represents an invagination of the body wall or an overlapping of the ventral wall of the body and is consequently ectodermal. Each oviduct in certain insects may be distended posteriorly to form the vagina which may also be distended for the retention of eggs or larvæ, as in the tsetse flies, *Glossina*, and the sheep tick, *Melophagus*, in which case the distended portion is termed the *uterus*.

Spermatheca or *receptaculum seminis* — sperm pouch or reservoir for storing the spermatozoa. It is usually ovoid or spherical but may be tubular or even branched in certain COLEOPTERA, and, being derived from the ectoderm, it has a chitinous lining. The wall is nonmuscular, and a finger-like gland is generally attached to it. "It is connected by a slender tube with the vagina. The sperm finds its way into this reservoir by passing up the vagina after copulation and out through this spermathecal duct to the spermatheca. As eggs pass down the vagina, contractions of the tube draw the spermatozoa back down the duct into the vagina" (Freeborn). In most female insects the spermatheca is a single organ, but there are two in certain COLEOPTERA (*Blaps*) and DIPTERA (*Flebotomus* and *Culex*) and three in many other members of the DIPTERA.

Colleterial or *sebific glands*. — These organs, consisting of one or two pairs, open into the lower portion of the vagina. They secrete gelatinous or mucus-

like substances employed in oviposition as an investment or attachment of the eggs and for the construction of the oötheca. They are especially well developed in the ORTHOPTERA, MANTODEA, and BLATTARIA which produce large oöthecæ and to a lesser degree in the LEPIDOPTERA and some other orders.

Bursa copulatrix or *copulatory pouch*. — "This may or may not be present in insects although technically speaking the portion of the female reproductive system which receives the spermatozoa from the male at the time of copulation could be so designated; however, the term is restricted to modifications of the tract for this specific purpose. Thus, in the honeybee, the distal end of the vagina is distended for this purpose. The most pronounced modification, however, is in the LEPIDOPTERA, where a special copulatory opening distinct from the vaginal opening is present leading into a flaccid pouch, the *bursa copulatrix*. This nonmuscular pouch is connected externally with the vagina by a slender tube. The spermatozoa, deposited in the bursa copulatrix, propel themselves up the connecting tube to the vagina and thence into the spermathecal duct and the spermatheca" (Freeborn).

Ovipositor or *egg-laying organ*. — This is a specialized terminal mechanism of frequent occurrence among insects which enables them to deposit eggs in places suitable for their protection and development, such as holes in ground, wood, leaves, fruits, and seeds, as well as on or in the eggs, larvæ, pupæ, and adults of other insects and also in certain related animals. It usually consists of three pairs of closely fitting unsegmented styles which serve not only as a drill for excavating a cavity but also as a tube for inserting the eggs. It varies in length from a small fraction of the length of the body to several times its total length. In bees and wasps the ovipositor has been modified into a sting.

MALE REPRODUCTIVE ORGANS

Gonads. — The male gonads are paired testes which are situated above, below, or beside the alimentary tract. As they are usually supported by the surrounding tissues, suspensory filaments are poorly developed or entirely absent. Each testis is a closed capsule that is divided into a series of follicles, chambers, or testicular tubes in whose walls are the follicles in which are located the germ cells that develop into the spermatozoa. The testes are of many types in the various insects. In the primitive APTERYGOTA they are similar in size and form to the ovaries, but in the more specialized PTERYGOTA they are much smaller than the ovaries of the female of a like species.

Follicles. — These organs vary greatly in form and organization among insects. Each consists of a simple enlarged chamber or sac in most APTERYGOTA, or it may appear as three or four bilobed chambers. The follicles are small single chambers in NEUROPTERA and DIPTERA, two-chambered in certain ANOPLURA, and include numerous globular or tubular organs in ORTHOPTERA. Each follicle may be joined to the *vasa deferentia* by a slender tube (*vas efferens*) as in ANOPLURA and some COLEOPTERA, or the testes may be wholly enveloped in a common pigmented coat known as the *scrotum*. Innumerable other intricate arrangements are found in various insects.

The follicles are lined with a layer of epithelial cells over which there is a peritoneal membrane. Each follicle is divided into a series of zones marked by the presence of sex cells in various stages of formation and development. The zones are designated as:

- (1) *Germarium* — the region of the primordial germ cells or spermatogonia which undergo multiplication.
- (2) *Zone of growth* — the region where the spermatogonia increase in size and develop into spermatocytes of the first and second orders.
- (3) *Zone of division and reduction* — the region where the spermatocytes undergo mitosis and produce spermatids.
- (4) *Zone of transformation*. — The paired gonoducts of the male are called *vasa deferentia*. They unite into a common short duct, the *ejaculatory duct*, which opens at the end of the *ædeagus*. They are of mesodermal origin and have an outer peritoneal coat, a middle region of muscle fibers, and an inner lining of epithelial cells. The ducts vary greatly in length, and in most insects each *vas deferens* is enlarged to form a sperm sac or reservoir, the *vesicula seminalis*, or both ducts may communicate to a single common *vesicula seminalis* in which the spermatozoa are held. This sperm reservoir has a powerful muscular coat consisting of an outer layer of circular fibers and an inner layer of longitudinal fibers within which is a zone of epithelial cells which secrete the chitinous lining of the *lumen* of the ejaculatory duct.

Spermatozoa. — The spermatozoa of insects are similar to those of other animals. Each spermatozoön consists of an enlarged region, the head, a short middle piece, and a vibratile tail of variable length and structure used for locomotion. The development of spermatozoa from primordial cells is called *spermatogenesis*.

Spermatophore. — Among certain insects in the ORTHOPTERA, ODO-NATA, and LEPIDOPTERA the spermatozoa are produced in masses and enclosed in a definite sac or spermatophore which is transferable to the genital passage of the female. Special means may be provided for securing the attachment of the spermatophore to the female.

Verson's cells — large cells occurring in connection with the sex cells in LEPIDOPTERA and certain other insects. Their exact function is unknown, but they are believed to aid in the nutrition of the germ cells (Imms, 1934).

Accessory glands. — One, two, or three pairs of accessory glands usually occur in connection with the ducts of the male sex organs. Little exact information about them is known except that they are tubular or sac-like in form and their secretions undoubtedly have something to do with the formation and function of the spermatophores since they are particularly well developed in the ORTHOPTERA and other insects which produce these sperm sacs. According to Escherich (1894) these glands are arranged into two groups: (1) *Mesadenia*, which are derived from the mesoderm as evaginations of the *vasa deferentia*, and (2) *ectadenia*, which are derived from the ectoderm as evaginations of the ejaculatory duct.

Genitalia. — The genitalia or intromittent organ of the male is more appropriately termed the *ædeagus*. It consists in a finger-like invagination of the ventral integument of the membrane between the ninth and tenth abdominal segments to receive the terminal section of the ejaculatory duct. The basal area which unites with the body is known as the *proximal* portion or *tegumen* and the distal part, called the *median lobe*, corresponds to the *penis* in many other animals. It may be retracted within the tegumen in repose. The *ædeagus* is often highly differentiated in the various insects and is extensively used by systematists in separating the species.

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CHAPTER III

CLASSIFICATION OF INSECTS

Class **INSECTA** Linnæus 1758 or **HEXAPODA** Latreille 1825

Subclass **APTERYGOTA (APTERYGOGENEA)**. Apterous Insects

1. Order **PROTURA** Proturans, Proturids
2. " **THYSANURA** Thysanurans, Bristletails, Silver Fish Moths, Slickers
3. " **APTERA** Campodeids, Iapygids
4. " **COLLEMBOLA** Springtails, Snow Fleas

Subclass **PTERYGOTA (PTERYGOGENEA)**. Largely Winged Insects

I. Division **EXOPTERYGOTA (HETEROMETABOLA)**. Insects with primitive or simple metamorphosis

5. Order **ORTHOPTERA** Locusts, Grasshoppers, Katydid, Crickets, Mole Crickets
6. " **GRYLLOBLATTODEA** . . Grylloblattids
7. " **BLATTARIA** Roaches, Cockroaches
8. " **PHASMIDA** Phasmids, Walkingsticks, Stick Insects
9. " **MANTODEA** Mantids, Preying Mantids, Praying Mantids, Soothsayers
10. " **DERMAPTERA** Earwigs
11. " **DIPLOGLOSSATA** Hemimerids
12. " **PLECOPTERA** Stoneflies, Salmonflies, Perlids
13. " **ISOPTERA** Termites
14. " **ZORAPTERA** Zorapterans
15. " **EMBIOPTERA** Embiids, Webspinners
16. " **CORRODENTIA** Psocids, Book Lice, Bark Lice, Dust Lice
17. " **MALLOPHAGA** Bird Lice, Biting Bird Lice
18. " **ANOPLURA** True Lice, Sucking Lice
19. " **EPHEMERIDA** Mayflies
20. " **ODONATA** Damselflies, Dragonflies, Devil's Darning Needles, Snakedoctors, Mosquito Hawks
21. " **THYSANOPTERA** Thrips
22. " **HEMIPTERA** Bugs, Cicadas, Treehoppers, Leafhoppers, Spittlebugs, Lanternflies, Psyllids, Aphids, Whiteflies, Scale Insects

II. Division **ENDOPTERYGOTA (HOLOMETABOLA)**. Insects with complex metamorphosis

23. Order **MEGALOPTERA** Orflies, Dobsonflies, Fishflies
24. " **NEUROPTERA** Nerve-winged Insects, Lacewings

25.	"	RAPHIDIODEA . . .	Raphidians, Snakeflies, Serpentflies
26.	"	MECOPTERA . . .	Scorpionflies
27.	"	TRICHOPTERA . . .	Caddisflies, Caddises, Caddiceflies, Caseflies, Water Moths
28.	"	LEPIDOPTERA . . .	Moths, Butterflies
29.	"	COLEOPTERA . . .	Beetles, Weevils
30.	"	STREPSIPTERA . . .	Strepsipterans, Stylops, Twisted- winged Insects
31.	"	HYMENOPTERA . . .	Ants, Bees, Wasps, Gallflies, Sawflies, Horntails, Ichneumons, Braconids, Chalcids
32.	"	DIPTERA . . .	Flies, Gnats, Midges, Mosquitoes, Punkies
33.	"	SIPHONAPTERA . . .	Fleas, Chigoes

Numbers of Species of Insects

According to Z. P. Metcalf (*Ent. News* 51: 219-222, 1940), approximately 1,500,000 species of insects have been described during the period from 1758 to 1940.

KEY TO ORDERS — ADULTS

1. Apterous or with inconspicuous vestigial wings. 2
 Fully winged or with rudimentary wings 25
2. Mouth parts mandibulate or for biting and chewing 3
 Mouth parts suctorial or for piercing and sucking 21
3. Mouth parts retracted within the head and with only the apical portions visible 4
 Mouth parts free and not retracted within the head 7
4. Abdomen composed of six or fewer segments, with ventral sucker and caudal springing apparatus. (Springtails.) **COLLEMBOLA** p. 77
 Abdomen 10- to 12-segmented, without ventral sucker and caudal springing apparatus 5
5. Abdominal segments I to III each with a pair of small ventral styli; antennæ and cerci absent; minute and rare. (Proturans.) . **PROTURA** p. 59
 Abdominal segments II to VII each with a pair of small ventral styli; antennæ and cerci or forceps present 6
6. Body usually covered with scales; long cerci and a median caudal filament present. (Bristletails.) **THYSANURA** p. 65
 Body smooth and without scales; cerci or a pair of forceps present; caudal filament absent. (Campodeids, Iapygids.) **APTERA** p. 72
7. Head prolonged into a beak. (Scorpionflies.) **MECOPTERA** p. 399
 Head normal, not prolonged into a beak 8
8. Small, soft or tough, crawling and running louse-like insects; prothorax small and inconspicuous 9
 Small or large, soft or well sclerotized insects; prothorax normal 10
9. Antennæ with five or fewer segments; ectoparasitic on birds and mammals. (Biting Bird Lice.) **MALLOPHAGA** p. 193
 Antennæ with more than five segments; phytophagous **CORRODENTIA** p. 184

10. Abdomen constricted at the base; cerci absent. (Ants, Wasps, and many parasitic forms.) **HYMENOPTERA** p. 619
 Abdomen not constricted at the base; cerci present 11
11. Tarsi two-segmented; cerci unsegmented. (Zorapterans.) **ZORAPTERA** p. 174
 Tarsi three-segmented, basal segment of fore tarsus swollen. (Embiids.) **EMBIOPTERA** p. 177
 Tarsi two- to five-segmented 12
12. Hind legs enlarged for jumping. (Grasshoppers, Katydid, Crickets.)
 ORTHOPTERA p. 87
 Hind legs normal, not specialized for jumping 13
13. Prothorax conspicuously lengthened; forelegs raportial. (Mantids.)
 MANTODEA p. 124
 Prothorax not greatly lengthened; forelegs normal. 14
14. Cerci absent; body well armored; antennæ usually 11-segmented. (Beetles, Weevils.) **COLEOPTERA** p. 518
15. Cerci usually unsegmented 16
 Cerci usually segmented 17
16. Cerci short, corneous, and forceps-like; not ectoparasitic on mammals; widely distributed species. (Earwigs.) **DERMAPTERA** p. 131
 Cerci relatively long and slender; ectoparasitic on rodents; rare South African species. (Hemimerids.) **DIPLOGLOSSATA** p. 145
17. Cerci three- or more segmented 18
 Cerci one- to three-segmented 19
18. Body flattened and oval; hypognathous, *i.e.*, head vertical and mouth parts directed downwards; prothorax normal. (Cockroaches.)
 BLATTARIA p. 109
 Body somewhat cylindrical; prognathous, *i.e.*, head horizontal and mouth parts directed forwards; prothorax quadrate. (Grylloblattids.) **GRYLOBLATTODEA** p. 105
19. Tarsi five-segmented; body long and stick-like or broad and flat or leaf-like. (Walkingsticks, Leaf Insects.) **PHASMIDA** p. 116
 Tarsi two- to four-segmented; body neither stick-like nor leaf-like 20
20. Tarsi apparently four-segmented; cerci two- to six-segmented; antennæ usually more than nine-segmented. (Termites.) . . . **ISOPTERA** p. 159
 Tarsi two-segmented; cerci unsegmented; antennæ nine-segmented; minute, rare species. (Grylloblattids.) . . . **GRYLOBLATTODEA** p. 105
21. Ectoparasites on birds and mammals 22
 Not ectoparasites on birds and mammals; largely phytophagous 24
22. Body strongly compressed laterally; rarely with vestigial wings; small jumping or burrowing insects. (Fleas.) **SIPHONAPTERA** p. 819
 Body not compressed laterally; crawling insects 23
23. Antennæ inserted in pits and not visible from above. (Louse Flies: PUPIPARA.) **DIPTERA** p. 728
 Antennæ exserted and plainly visible from above. (Sucking Lice.)
 ANOPLURA p. 202
24. Apical segment of tarsus terminating in a bladder-like organ and without well-developed claws. (Thrips.) **THYSANOPTERA** p. 247
 Apical segment of tarsus not bladder-like and terminating in well-developed claws (HOMOPTERA). **HEMIPTERA** p. 263

25. One pair of wings present 26
 Two pairs of wings present 28
26. Abdomen with caudal filaments 27
 Abdomen without caudal filaments. (Flies.) **DIPTERA** p. 728
27. Halteres, or small knobbed organs representing the hind wings, absent;
 wings with many veins. (Few Mayflies.) **EPHEMERIDA** p. 211
 Halteres present; wings with a simple forked vein; minute fragile in-
 sects usually with two terminal abdominal filaments. (Male Coccids:
HOMOPTERA.) **HEMIPTERA** p. 263
28. Fore and hind pairs of wings unlike in structure, the fore pair thick-
 ened, leathery or horny, the hind pair membranous. 29
 Fore and hind pairs of wings alike in structure; membranous 35
29. Fore wings reduced to slender club-shaped appendages; very small
 and rather rare insects. (Strepsipterans.) **STREPSIPTERA** p. 609
 Fore wings with bases thickened and frequently opaque and the apical
 portions membranous; mouth parts for piercing and sucking.
 (Bugs.) **HEMIPTERA** p. 263
 Fore wings of the same texture throughout 30
30. Fore wings leathery or horny, without veins, and functioning as covers
 of the hind wings 31
 Fore wings leathery or parchment-like with a network of veins; hind
 wings folded fan-like beneath the fore pair 32
31. Fore wings short and never entirely covering the abdomen; abdomen
 terminating in a pair of movable forceps. (Earwigs.) **DERMAPTERA** p. 131
 Fore wings partially or completely covering the abdomen; abdomen
 without terminal forceps. (Beetles, Weevils.) **COLEOPTERA** p. 518
32. Hind femora usually enlarged for jumping (in **GRYLLOTALPIDÆ**
 or mole crickets the hind legs are normal whereas the forelegs are
 broad and fossorial); body somewhat cylindrical or compressed
 laterally; wings held more or less roof-like in repose; tergites usually
 larger than the sternites; stridulating organs present. (Grasshop-
 pers, Katydid, Crickets.) **ORTHOPTERA** p. 87
 Hind femora not enlarged for jumping; body somewhat compressed
 dorsally; wings resting flat over the body; tergites and sternites sub-
 equal; stridulating organs absent 33
33. Body elongate; head free and uncovered; slow-moving insects 34
 Body oval and flattened; head partially or wholly concealed beneath
 the pronotum; swift-running species. (Cockroaches.) . **BLATTARIA** p. 109
34. Prothorax greatly elongated; forelegs raptorial or specialized for
 catching and holding living prey; cerci usually more than one-seg-
 mented. (Mantids.) **MANTODEA** p. 124
 Prothorax short; legs similar; cerci simple; stick-like or leaf-like in-
 sects. (Walkingsticks, Leaf Insects.) **PHASMIDA** p. 116
35. Last tarsal segment terminating in a bladder-like organ, without well-de-
 fined claws; wings usually fringed with hairs. (Thrips.) **THYSANOPTERA** p. 247
 Last tarsal segment terminating in well-developed claws 36
36. Wings partially or more often entirely covered with scales; mouth
 parts for sucking. (Moths, Butterflies.) **LEPIDOPTERA** p. 421
 Wings transparent or but thinly clothed with hairs 37

37. Mouth parts arising from the underside of the base of the head near the fore coxæ, enclosed in a jointed rostrum for sucking. (HOMOPTERA: Cicadas, Leafhoppers, Aphids, Scales, etc.) . . . **HEMIPTERA** p. 263
- Mouth parts normally situated at the front of the head . . . 38
38. Wings net-veined, with many longitudinal and cross veins . . . 39
- Wings not net-veined, with branching and few cross veins . . . 40
39. Tarsi with less than five segments . . . 40
- Tarsi five-segmented . . . 44
40. Antennæ inconspicuous, small, short, setiform . . . 41
- Antennæ conspicuous and of many forms . . . 42
41. Fore and hind wings nearly equal in size; tarsi three-segmented. (Damselflies, Dragonflies.) . . . **ODONATA** p. 228
- Fore wings much larger than the hind wings; tarsi four-segmented. (Mayflies.) . . . **EPHEMERIDA** p. 211
42. Tarsi two- or three-segmented . . . 43
- Tarsi three-segmented; fore tarsi enlarged; males only winged. (Embiids.) . . . **EMBIOPTERA** p. 177
- Tarsi four-segmented; wings nearly equal. (Termites.) . . . **ISOPTERA** p. 159
43. Fore wings equal to or narrower than the hind wings. (Stoneflies.) . . . **PLECOPTERA** p. 148
- Fore wings larger than the hind wings. (Psocids.) . . . **CORRODENTIA** p. 184
44. Abdomen with long, filiform, many-segmented caudal filaments. (Certain Mayflies.) . . . **EPHEMERIDA** p. 211
- Abdomen without long many-segmented caudal filaments . . . 45
45. Head prolonged into a beak. (Scorpionflies.) . . . **MECOPTERA** p. 399
- Head not prolonged into a beak . . . 46
46. Prothorax quadrate or nearly so; hind wings plicated or the anal area folded fan-like in repose; aquatic species . . . 47
- Prothorax cylindrical or subcylindrical; hind wings may be rarely folded fan-like in repose; mostly terrestrial species (TRICHOPTERA have hind wings folded and are aquatic.) . . . 48
47. Cerci long and slender, many-segmented; wings folded flat and closely over the body in repose. (Stoneflies.) . . . **PLECOPTERA** p. 148
- Cerci absent; wings folded loosely or roof-like over the body in repose. (Dobsonflies, Fishflies, Sialids.) . . . **MEGALOPTERA** p. 366
48. Prothorax very long and slender; wings subequal. (Serpentflies.) . . . **RAPHIDIODEA** p. 394
- Prothorax not greatly lengthened; wings dissimilar . . . 49
49. Tarsi two- or three-segmented . . . 50
- Tarsi four- or five-segmented . . . 51
50. Cerci present; body less than 3 mm. in length. (Zorapterans.) **ZORAPTERA** p. 174
- Cerci absent; body 3 mm. long or longer. (Psocids.) **CORRODENTIA** p. 184
51. Abdomen with long many-segmented caudal filaments. (Certain Mayflies.) . . . **EPHEMERIDA** p. 211
- Abdomen without long caudal filaments. . . . 52
52. Prothorax heavily sclerotized or horny; fore wings larger than hind wings, the latter with but few simple veins; mandibles well developed; palpi short. (Sawflies, Horntails, Gallflies, Ants, Wasps, Bees.) . . . **HYMENOPTERA** p. 619

- Prothorax thin and membranous or parchment-like; hind wings equal to or larger than the fore wings; all wings with many veins; mandibles small; palpi long and conspicuous 53
53. Both pairs of wings nearly equal in size, not folded, held roof-like over the body in repose; terrestrial and aquatic. (Dustywings, Ant Lions, Lacewings, Golden Eyes, Spongilla Flies.) **NEUROPTERA** p. 372
- Hind wings equal to or more often larger than the fore wings, folded lengthwise; wings held flat over or around the sides of the body in repose; aquatic. (Caddisflies.) **TRICHOPTERA** p. 407

CHAPTER IV

1. Order PROTURA Silvestri 1907¹

(Pro-tu'ra, from Greek *πρῶτος*, first, + *οὐρά*, tail. According to Imms the name is derived from the simple telson-like 12th segment.) German, Proturen. French, Protures.

Proturans.

Very minute, slender, white, apterous insects with primitive metamorphosis; inserted biting mouth parts; without eyes, but with a pair of pseudoculi;² without visible antennæ; pointed head; nine-segmented abdomen in young and twelve-segmented in adult, the first three segments each with a pair of small one- or two-segmented ventral appendages or pectines; without cerci; with anamorphosis or increase in number of body segments during postembryonic development.

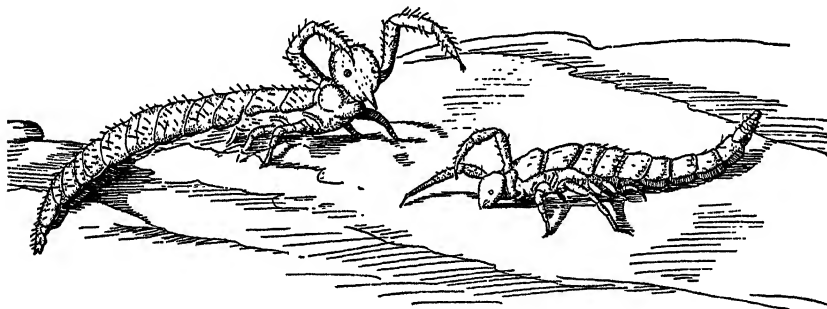


FIG. 23. Natural aspects of proturans. Left, *Acerentomon doderoi* Silvestri; right, *Eosentomon transitorium* Berlese. The forelegs function as antennæ. (Redrawn from Berlese.)

The order PROTURA was erected by F. Silvestri in 1907 with *Acerentomon doderoi* Silvestri as the first described genus and species. This species was taken in humus soils at Geneva, Switzerland, and at other localities in Italy and has since been reported in other parts of Europe and in the United States (California). Other species have been taken from many parts of Europe, Oriental Asia, and the United States. Silvestri described the first North American species, *Eosentomon wheeleri*, from New York in 1909. A second American species was discovered near Washington, D. C., by H. S. Barber in 1920 and named *Acerentulus barberi* by H. E. Ewing in 1921. The first species from west-

¹ These insects have been variously classified as MYRIENTOMATA Berlese 1909, PROTHYSANURA Schepotieff 1909, ELLIPURA Börner 1910, ANAMERENTOMA Prell 1912, and PANPROTURA Crampton 1920. Ewing 1910 suggests that they be placed in a separate class PROTURA of the ARTHROPODA.

² These are now thought to be rudimentary antennæ (Ewing). Also spelled *pseudocelli*.

ANATOMICAL CHARACTERS

External	Internal
<p>Size — minute, 0.5-2.0 mm. long.</p> <p>Shape — elongate, some very slender.</p> <p>Exoskeleton — whitish, soft, with few simple spines.</p> <p>Head — pyriform or nearly circular.</p> <p><i>Tentorium</i> — “developed from hypopharyngeal apodemes into a ventral rod-like structure which is primarily and secondarily forked” (Ewing).</p> <p><i>Eyes</i> — none.</p> <p><i>Antennæ</i> — the pair of so-called pseudoculi are thought to be rudimentary antennæ.</p> <p><i>Mouth parts</i> — piercing, internal (entognathous).</p> <p><i>Labrum</i> — absent, spine-like, or tubercular.</p> <p><i>Mandibles</i> — needle-like.</p> <p><i>Maxillæ</i> — with outer and inner lobe, one or both piercing.</p> <p><i>Palpi</i> — three- or four-segmented.</p> <p><i>Labium</i> — composed of base and pointed glossæ.</p> <p><i>Palpi</i> — two- to three-segmented.</p> <p>Thorax — prothorax much reduced.</p> <p><i>Legs</i> — three pairs; forelegs held above head like antennæ; <i>tarsi</i> — one-segmented; <i>claw</i> — single; <i>empodium</i> — bristle-like.</p> <p><i>Wings</i> — absent.</p> <p><i>Spiracles</i> — one pair each on the mesothorax and metathorax.</p> <p>Abdomen — with nine segments at birth and three added between the last two segments, making 12 in adult; last three segments telescoped.</p> <p><i>Spiracles</i> — absent.</p> <p><i>Cerci</i> — absent.</p> <p><i>Genitalia</i> — reproductive ducts of both sexes open behind the penultimate segment.</p> <p><i>Special appendages</i> — three pairs of short one- or two-segmented ventral appendages terminating in eversible sacs.</p> <p><i>Apodemes</i> — strongly chitnized bands on the front edge of each tergite.</p> <p><i>Pectines (Pectinæ)</i> — small combs on the posterior lateral angles of the tergites.</p> <p><i>Dorsal glands</i> — pairs of segmentally arranged openings which discharge a viscous secretion.</p>	<p>Digestive System. Simple.</p> <p><i>Alimentary canal</i> — simple, straight tube with enlarged cylindrical stomach; two pairs of maxillary and one pair of labial or salivary glands.</p> <p><i>Malpighian tubules</i> — represented by six uni- or bi-cellular papillæ arranged in two groups.</p> <p>Circulatory System. Unusual: with a non-pulsating longitudinal dorsal <i>pericardial cord</i>.</p> <p>Respiratory System. Tracheæ simple, two pairs, or absent.</p> <p>Nervous System. Brain; suboesophageal and prothoracic ganglia; separate ganglia in the meso- and metathorax; first five abdominal segments with double connectives; terminal ganglion largest, supplementary ganglia on each pedal nerve at base of legs (Imms, 1934). Special sense organs on the forelegs.</p> <p>Reproductive System. Each gonad consists typically of a single egg tube or sperm tube or in one case (needing further confirmation) of three pairs of egg tubes (Ewing).</p> <p><i>Male</i> — ducts long and curled; open through genital organs exerted between the 11th and 12th abdominal segments.</p> <p><i>Female</i> — oviducts unite in the eighth abdominal segment to form a median duct.</p>

ern North America was collected by Ewing in decaying leaves in the Yosemite Valley, Calif., April 15, 1927, and described as *Eosentomon yosemitensis* by Ewing the same year. In recent years many species have been discovered in North America, especially from Maryland, New York, Pennsylvania, Virginia, North Carolina, Illinois, Arkansas, Louisiana, Florida, Texas, Iowa, California, and Mexico. In California a second species, *Acerentulus californicus*, was collected in a canyon near Claremont and described in 1929 by W. A. Hilton, who has discovered proturans in many parts of southern California. Ewing has described most of the American species. So far practically nothing is known concerning the life histories and food habits of these primitive insects. Those collected have been found in damp situations under leaves, bark, and stones, in rotten wood, decaying vegetation, turf, and humus soils.

Proturans are peculiar in that they walk only on the middle and hind legs and hold the fore pair in front of and above the head as tactile organs, not unlike some of the ARACHNIDA.

They have been placed in a separate class, MYRIENTOMATA Berlese, or PROTURA (Silvestri) by some entomologists because of certain affinities with CHILOPODA and SYMPHYLA, but most modern authors agree that they are sufficiently closely related to insects to warrant their inclusion in the INSECTA.

Noninsect Characters

1. No antennæ.
2. Position of the genital aperture behind the penultimate segment.
3. Anamorphosis — the acquisition of three abdominal segments after birth.
4. Reduction or loss of tracheal system.

Insect Characters

1. Differentiated thorax.
2. Three pairs of legs.
3. Mouth parts very similar to those in the COLLEMBOLA.

There are approximately 62 species described from various parts of the world, of which 23 are Nearctic, two Neotropical, 27 Palæarctic, two Oriental, one Ethiopian, and six Australian.

KEY TO FAMILIES¹

(After Ewing, 1940)

1. Tracheæ present; a pair of spiracles on the mesothorax and also on the metathorax; all vestigial abdominal appendages two-segmented; abdominal segment VIII without pectines **EOSENTOMIDÆ** p. 62
- Tracheæ and spiracles absent; pectines on abdominal segment III one-segmented; abdominal segment VIII with a pair of pectines 2
2. Abdominal terga each with one or three transverse sutures and a pair of laterotergites; abdominal segments with two complete transverse rows of dorsal setæ; abdominal segment VIII with obvious pectines **ACERENTOMIDÆ** p. 63

¹ The superfamily and family endings oidea and idæ are derived from the Greek *εἶδος*, meaning something seen, a form, shape, figure, species, kind.

3. Abdominal terga without transverse sutures and laterotergites; abdominal segments each with a single, complete transverse row of dorsal setae; abdominal segment VIII with pectines absent or reduced

PROTENTOMIDÆ p. 63

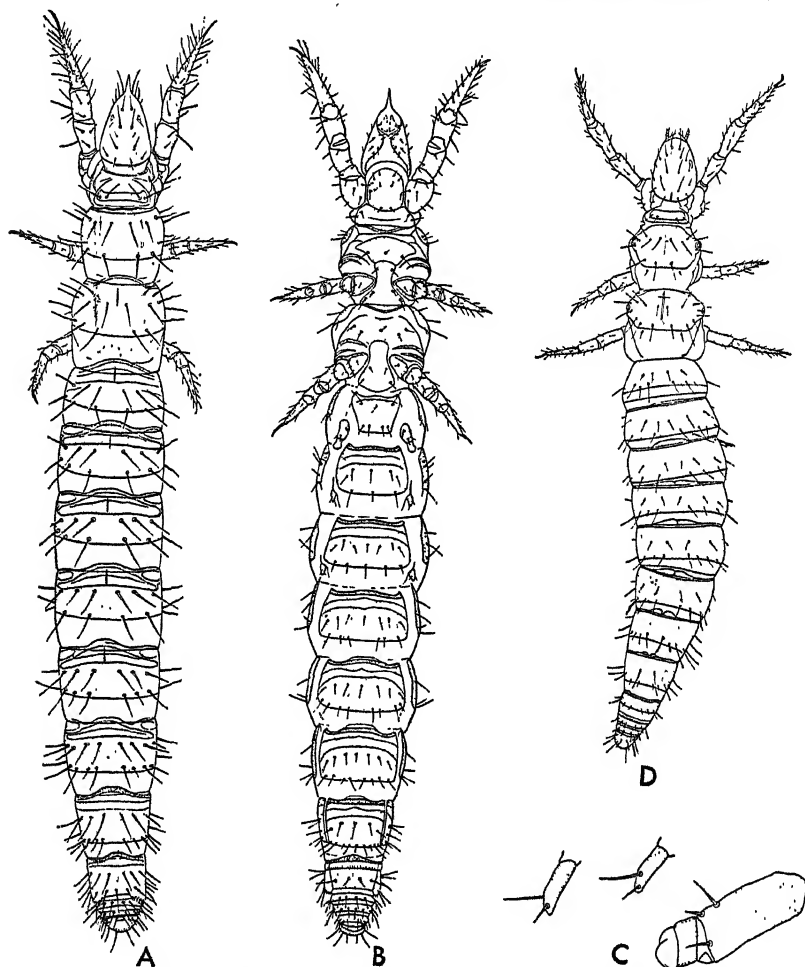


FIG. 24. Proturans. A, dorsal and B, ventral aspects, and C, styli of *Acerentomon doderoi* Silvestri; D, dorsal aspect of *Eosentomon ribagai* Berlese. (Redrawn from Berlese, 1909.)

Family EOSENTOMIDÆ Berlese 1909 (E'o-sen-tom'i-dæ, from the Greek ἥως, dawn, early, + ἔντομα, insects; referring to the primitive nature of these insects).

The only known genus is *Eosentomon* Berlese. It contains 14 species: six in Europe, two in tropical Asia, and seven in North America.

Family ACERENTOMIDÆ Berlese 1909 (Ac'er-en-tom'i-dæ, from the Greek ἀκέρατος, without horns, + έντομα, insects; referring to the absence of antennæ).

The known genera are: *Acerentomon* Silvestri (17 species: 10 Europe, five North America, two Europe and North America); *Acerentulus* Berlese (*Acerentuloides* Ewing, *Acerella* Ewing) (14 species: six Europe, seven North America, one Europe and North America).

Family PROTENTOMIDÆ Ewing 1936 (Pro'ten-tom'i-dæ, from the Greek πρῶτον, first, + έντομα, insect; referring to their primitive condition).

The known genera are: *Micræntomon* Ewing (one species in Europe); *Protentomon* Ewing (one species in North America); and *Proturentomon* (*Paræntomon* Womersley, *Parentomon* Womersley) (three species: two Europe, one North America).

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CHAPTER V

2. Order THYSANURA Latreille 1796¹

(Thy'sa-nu'ra, from the Greek *θύσανος*, a tassel, fringe, + *οὐρά*, tail.)

Thysanurans, Bristletails, Silver Fish Moths, Slickers.

Small, primitive, apterous insects with elongated, flattened, naked, or scaly bodies; soft integument; primitive metamorphosis; biting mouth parts, maxillæ long; antennæ long and many-segmented; compound eyes well developed, vestigial, or absent; ocelli present or absent; coxæ small; tarsi two- or three-segmented, with two or three claws; abdominal styloform appendages; cerci long, many-segmented; long, many-segmented median caudal filament.

Among the most primitive of insects, the members of this small order are remarkable for their almost universal distribution. They are usually white, gray, brown, or otherwise pigmented to harmonize with their immediate surroundings on the ground, among dry or wet leaves, on rocks, logs, tree trunks, and other similar places. Because they are entirely apterous and dependent upon crawling, running, and jumping to move about, and because of their fast movements and scaly bodies, they are variously known as bristletails, silver fish moths, and slickers in English; as Zottenschwänze, Felsenspringer, and Fischchen in German; and as Thysanoures in French.

External anatomy. — The bodies have the appearance of being naked, but in fact they are usually somewhat hairy or are covered with overlapping metallic scales and look like miniature dragons. The head is comparatively wide and not constricted behind. The long antennæ may be composed of 30 or more thread-like segments. The com-

¹ Linnaeus, in 1735, erected the order *APTERA* to include all of the apterous insects, such as the bristletails, springtails, termites, biting and sucking lice, fleas, and many other animals such as the *CRUSTACEA*, *ARACHNIDA*, *CHILOPODA*, *DIPLOPODA*, and even certain of the *ANNULATA*. In the 10th edition of *Systema Naturæ* (1758) he included only members of the phylum *ARTHROPODA*. Fabricius also included these and some others in his *SYNISTATA* in 1775. In 1796 Latreille placed all of the primitive apterous insects in the order *THYSANURA* (*THYSANOURES*). The order was redefined in much the same way by Leach in 1815. In 1862 Sir John Lubbock defined the order in more specific terms that have been recognized until very modern times. Recently the new order *APTERA* has been separated off, thus restricting the *THYSANURA* to a very small group of insects.

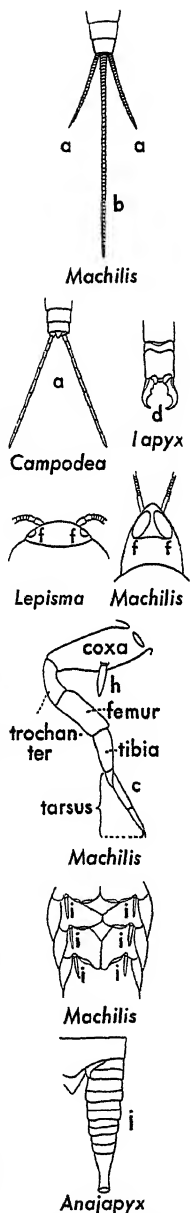


FIG. 25. Drawings showing some of the generic characters of the *THYSANURA* and the *APTERA*.

pound eyes are large and prominent or vestigial and even totally absent, and ocelli are present in relatively few forms. The mandibles are slender, entire or in two parts; the maxillary palpi are composed of four, five, or seven

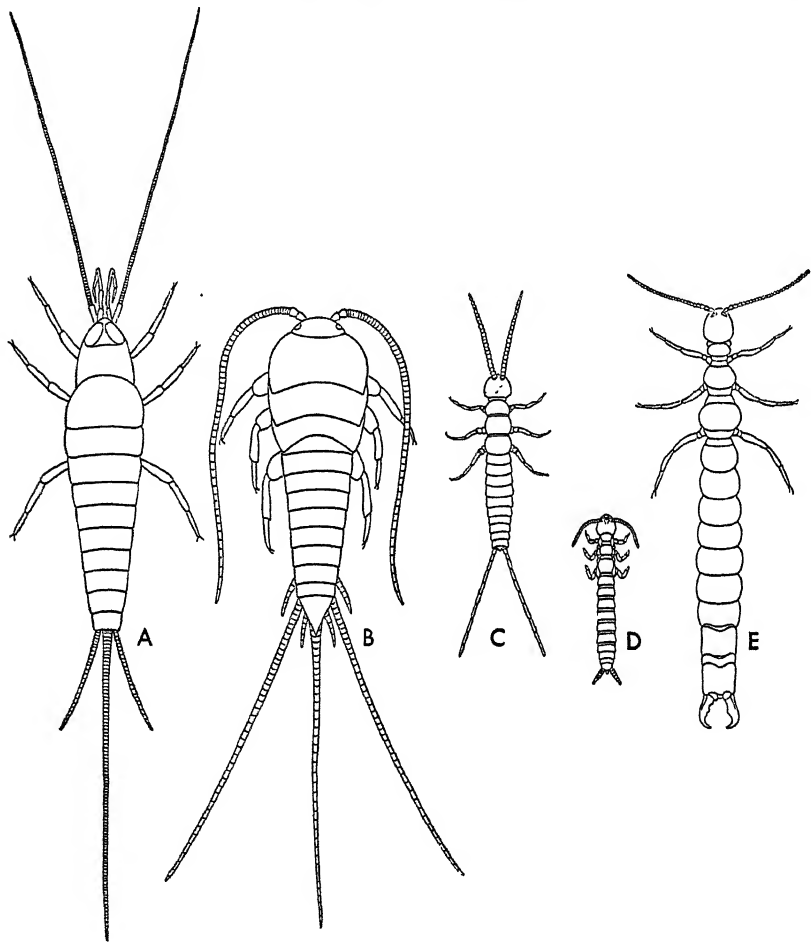


FIG. 26. Comparative sizes of some species of THYSANURA and APTERA. A, *Machilis maritima* Leach (after Lubbock); B, *Acratelsa collaris* Escherich (after Escherich); C, *Campodea staphylinus* Westwood (after Lubbock); D, *Anajapyx vesiculosus* Silvestri (after Imms); E, *Iapyx solfugus* Haliday (after Lubbock).

segments, the incisor and molar areas being wide apart; and the labial palpi are three-segmented. The thorax forms the widest region of the body. The legs are similar, and in the machilids there are one or more movable styli or exopodites on each of the middle and hind coxæ. The tarsi are composed of three or four segments with paired claws. The abdomen is composed of 10

complete segments, and the 11th segment is often modified into the median caudal filament. There is a pair of styli and one or two pairs of eversible sacs on a variable number of abdominal sternites. The cerci, often consisting of 50 or more similar segments, arise from the 10th segment.

Internal anatomy.—The digestive tract consists of a large or small gizzard and a tube, either straight or with a single convolution in the hind intestine. Enteric cæca and salivary glands are present. Malpighian tubules are well developed and consist of four to eight in the lepismids and 12 to 20 in the machilids. There are normally two pairs of thoracic and seven or eight pairs of abdominal spiracles and three thoracic and eight abdominal ganglia.

The habitat of these insects is quite variable. Perhaps the majority of the species prefer damp places under leaves, debris, bark; in rotten wood, mosses, lichens; on stones and trunks and limbs of trees; and in the nests of ants and termites. A great many species, however, are found in comparatively dry, hot places on the surface of sun-baked soil; among dry leaves and grasses; on warm exposed rocks, in dry hollow logs, caves, stumps, and other natural shelters; and in buildings, particularly in the basements, kitchens, and around stoves, ovens, furnaces, and fireplaces. They are both diurnal and nocturnal; and are somewhat omnivorous in their feeding habits. Most of them are vegetarians that eat dry or decaying vegetation, fungi, lichens, mosses, and similar plant materials. House-inhabiting forms feed on cereals, pastes, glues, and paper, as well as starched clothing and sized silks and rayons. They may rarely eat woollen goods and other animal products.

Little is known about their biology. They are apparently largely oviparous, depositing their eggs in cracks and crevices out of sight. There are six or more instars, and under favorable conditions of the tropics maturity is reached in less than a year while in the temperate regions two or more years are required to complete a generation.

KEY TO FAMILIES

1. Compound eyes large contiguous or approximate; two ocelli present; styli usually present on the middle and hind coxæ; abdominal styli on sternites 2-9; tarsi three-segmented **MACHILIDÆ**
2. Compound eyes small and widely separated, or absent; ocelli absent; styli absent on coxæ; abdominal styli on sternites 7-9 or 8-9; tarsi three- or four-segmented **LEPISMIDÆ** p. 69

Family MACHILIDÆ Grassi 1888 (Ma-chil'i-dæ, derivation obscure), Machilids.

The members of this family are among the largest in the order, averaging from 10-12 mm. in length, and are characterized by their somewhat cylindrical scaly bodies which are widest through the thoracic region, the long antennæ, and the long caudal cerci and filaments; the latter are often longer than the body. The compound eyes, which are well developed in this family, are large,

contiguous or approximate dorsally, and the ocelli are elongate or arranged in groups in front of the compound eyes. They inhabit grassy and wooded areas, some species living in wet and others in dry places in the grass, among leaves, in dead wood, under bark and stones, among roots in the soil, or on rocks covered with lichens, while others are tenants in caves and small holes in the ground and a few inhabit termite nests. Ordinarily they move rather slowly but when

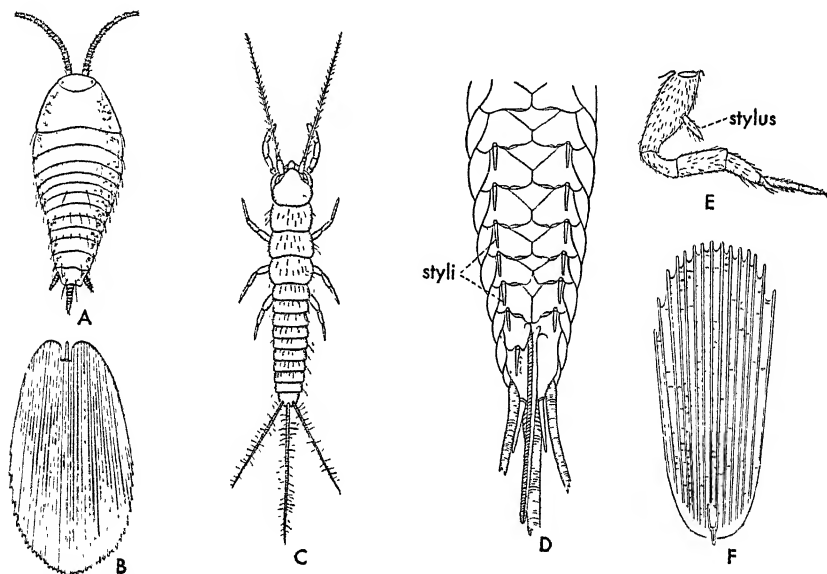


FIG. 27. Characters of THYSANURA. A, *Atelura lepismoidea* Folsom (after Folsom); B, a scale of *Lepisma*; C, *Nicoletia phytophila* Gervais (after Nicolet); D, ventral aspect of abdomen; E, mesothoracic leg; and F, body scale of *Machilis maritima* Leach (after Oudemans.)

disturbed jump with great agility. Their food appears to be various forms of dried or decayed vegetation. No species are recorded as pests of living plants or of the household. The individuals are best collected in an empty shell vial by placing the open ends over the insects, allowing them to jump into it, and immediately transferring the specimens to a bottle of 80 per cent alcohol where they may be kept until ready for study. Permanent mounts may be made in balsam, euparal, or other media on glass slides; or freshly killed specimens may be preserved in good condition in riker mounts if care is taken in handling them. The latter method is especially desirable for laboratory studies in general entomology.

There are approximately 30 genera, 150 species, and three subfamilies known. They are most abundant in the Palearctic region, where nearly half of the species have been collected. The other regions follow in order of number of species: Nearctic, Indo-Malaysian, Neotropical, Ethiopian, and other regions

with only a few each. Further study will probably result in finding a great many more representatives throughout the entire world.

The more important genera are: *Machilis* Latreille, which is known in North America, Europe, and Asia; *Machilellus* Silvestri, in Central America, Africa, Malaysia, and in the Galapagos Islands; *Assmuthia* Escherich, a termitophilous genus in India; *Machilinus* Silv., in North America and Europe; *Machiloides* Silv., in North and South America; *Nesomachilis* Tillyard, in New Zealand; *Mesomachilis* Silv., *Neomachilis* Silv., and *Petrobius* Leach (*Petrobius*) in North America.

Family LEPISMIDÆ Lubbock

1873 (Le-pis'mi-dæ, from the Greek *λεπίς*, a scale; referring to the scales on the body). Bristletails, Silverfish, Fish moths, Slickers.

The bodies of these insects are elongated, flattened, widest in the thoracic region and covered with scales, which latter are absent in the genus *Nicoletia*. The antennæ, cerci, caudal median filament, and palpi are prominent. The compound eyes, often represented by a group of ommatidia, are small and wide apart. They occur in the genera *Lepisma* Linn., *Isolepisma* Escherich, *Ctenolepisma* Esch., *Acrotelsa* Esch., *Thermobia* Bergroth, and *Silvestrella* Esch. The genera *Nicoletia* Gervais, *Lepidospora* Esch., *Atelura* Heyden, *Gastrotheus* Casey, and *Lepismina* Gervais are blind and live in the nests of ants or termites.

The members of the family are widely distributed, and, through commerce, some species have become almost cosmopolitan. Some 50 genera and 200 species are known. The Ethiopian region leads the list of species, followed by the Palæarctic, Neotropical, Nearctic, Australasian, and Oceanic regions. They

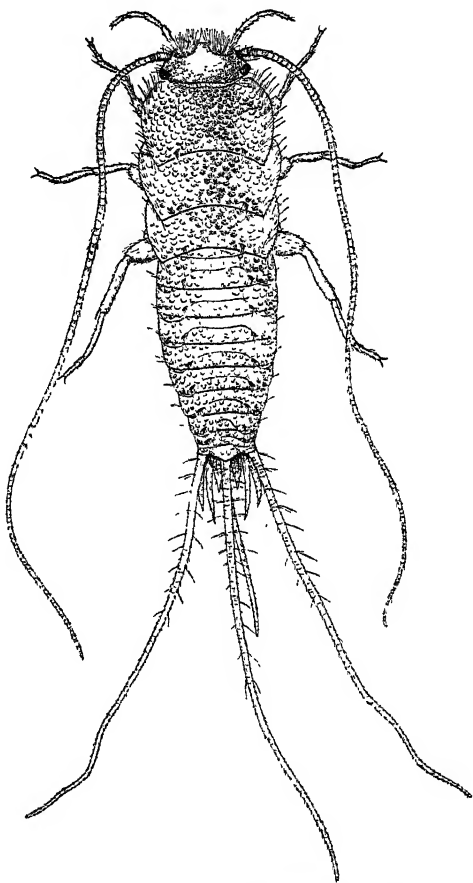


FIG. 28. The fire brat, *Thermobia domestica* (Packard).

inhabit dry hot places among leaves, under stones, debris, caves, buildings, and the nests of ants and termites. Those in buildings are chiefly nocturnal. They feed upon dry vegetation or plant products and those in houses are fond of paste and glue, to secure which they often injure pasteboard boxes or book-bindings. They are also fond of starched goods and rayon cloth. The silver fish moth, *Lepisma saccharina* Linnæus, is now almost cosmopolitan in distribution, being known in North America, Europe, China, Japan, and the Hawaiian Islands. The fire brat, *Thermobia domestica* (Packard), commonly occurs in buildings in this country and in Europe, New Zealand, and elsewhere. These domesticated species appear at night and especially frequent basements, kitchens, and warm places. The fire brat favors the warm or hot bricks about fireplaces, chimneys, furnaces, and ovens and is distinguished by its mottled gray color whereas the former species is of a uniform silver-gray or brownish color. *Ctenolepisma longicaudata* Escherich, a native of South Africa, has also been introduced into Australia and invades the houses there.

The members of the genus *Nicoletia* are devoid of body scales. They are rather slender in form and tropical and subtropical in distribution, occurring in South and Central America. They are termitophilous in habits. The members of the genus *Atelura* are almost heart-shaped, with very short antennæ and caudal appendages. They are quite commonly found in the nests of termites in South America.

The insects of this family are collected in the same manner as the machilids.

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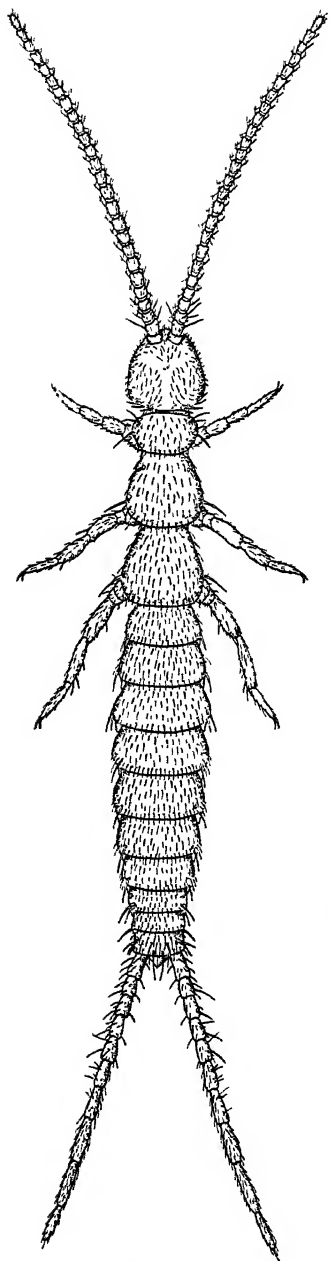


FIG. 29. *Campodea folsomi* Silvestri
of North America.

CHAPTER VI

3. Order APTERA¹ Linnæus 1758

(Ap'ter-a, from the Greek *á-*, without, + *πτερά*, wings; referring to the wingless condition of these insects.)

Campodeids, Iapygids, Projapygids.

Small, white or pale, blind, flattened, apterous insects greatly resembling thysanurans; with biting mouth parts; primitive metamorphosis; antennæ long, many-segmented; coxal appendages absent; tarsi one-segmented; styli on certain abdominal sternites; cerci long and many-segmented, short with apical openings, or replaced by a pair of short sclerotized pincers; without a median caudal filament.

These small, fragile, slender insects rarely attain a length of more than 8-10 mm. and are usually white in color because of their secluded and subterranean habits. They have rather long antennæ and either long or short cerci which may be replaced by a pair of short, darker, sclerotized pincers or forceps.²

¹ In the revisions of the Linnæan order APTERA it was early noted that many insects included therein rightfully belonged to other existing orders to which they have been assigned from time to time. New orders were also erected to provide for certain natural groups not otherwise disposed of. Latreille in 1796 separated off the order THYSANURA; Lubbock in 1870 established the order COLLEMBOLA; and Silvestri in 1907 founded the order PROTURA, a group of minute apterous insects unknown to the earlier entomologists. In 1888 Grassi designated the remaining members of the order APTERA as the THYSANURA ENTOTROPHA and in 1890 as the ENTOTROPHI. These members included the families IAPYGIDÆ and CAMPODEIDÆ. They were subsequently referred to as the ARCHINSECTA by Haeckel 1896, CAMPODEOIDEA by Handlirsch 1903, DIPLURA by Börner 1904; HOLOMERENTOMA by Prell 1912, and PANTHYSANURA by Crampton 1920. The order APTERA cannot be deprived of all of its members, so it appears logical that these remaining families, or at least certain of them, should constitute this order as employed in this work.

² Other insects with terminal abdominal pincers are earwigs and panorpid.

In general they have much in common structurally with their near relatives, the THYSANURA, from which they have only recently been separated. Some of the chief points of difference are: the absence of compound eyes and ocelli; less primitive mouth parts enclosed within the head, which characteristic gives the name to the order (the mandibles are entire, toothed, and, in some cases, have a small plate-like appendage, *lacinia mobilis*, near the apex); the maxillary and labial palpi greatly reduced or atrophied; the coxal styli or exopodites absent; the tarsi one-segmented; the 11th abdominal tergum comprises a small suranal plate; the abdominal styli occur on sternites 1-7 or 2-7; single pairs of protrusible vesicles on abdominal sternites 1-7, 2-7, on 2, or totally absent; the cerci variable as already indicated; the Malpighian tubules wanting or represented by papillæ; the number of thoracic and abdominal spiracles varying from three to 11 pairs; and three thoracic and seven or eight abdominal ganglia are present.

These insects definitely shun the light and are to be found most abundantly in damp places under dead leaves, vegetable mold, litter, rocks, logs, bark, and in soils rich in humus. They move with alacrity and seek concealment as rapidly as possible. Their food consists of living and dead vegetable matter, fungi, and perhaps also tiny animal life. They are widely distributed throughout the temperate and tropical regions of the world, there being about 100 described species.

KEY TO FAMILIES

1. Cerci not segmented, pincer-like. (Adult iapygids.) IAPYGIDÆ p. 74
Cerci segmented 2
2. Cerci open apically PROJAPYGIDÆ p. 74
Cerci not open apically 3
3. Cerci as long as or longer than the antennæ. (Campodeids.)
CAMPODEIDÆ
Cerci shorter than the antennæ. (Young iapygids.) . . . IAPYGIDÆ p. 74

Family CAMPODEIDÆ Westwood 1873 (Cam'po-de'i-dæ, from the Greek κάμπη, caterpillar, + ἔδος, form). Campodeids.

The members of this family are small, delicate, white, with slender flattened bodies and with long conspicuous antennæ and a pair of long cerci. They are blind and occur in damp conditions as indicated above. They may be readily reared in the laboratory in small closed glass or porcelain dishes. As they move rapidly and are so fragile they must be captured with care and preserved in 70 per cent alcohol. Permanent slide mounts may be made directly from 95 per cent alcohol into a medium such as De Faure's Fluid ³ and then ringed with cement.

³ Gum arabic	30 grains
Chloral hydrate	50 "
Glycerin	20 cc.
Distilled water	50 "
Chlorhydrate of cocaine	0.5 gram
Mix and filter.	

Although little is known about these insects, they appear to have a general, world-wide distribution. There are approximately 20 described genera and 75 species of which the greater number have been taken in the Palearctic, Nearctic, and Neotropical regions with very few known in the Oriental, Ethiopian, and Oceanic regions. The best known species is *Campodea staphylinus*, described in England by Westwood in 1842, which occurs in many parts of Europe and has often been erroneously reported in North America. In this country, *Campodea fragilis* Meinert (*C. americana* Packard) is one of the first known

species. It was described in Europe in 1865 and first noted in Massachusetts by Packard in 1871. It occurs in the North Atlantic states. Many little-known species have recently been described from North America. Probably the largest known species is *Campodea philpotti* Tillyard, of New Zealand, which is 7 mm. long, and the smallest is *C. montgomeryi* Silvestri, of Mexico, which is only 1.9 mm. in length.

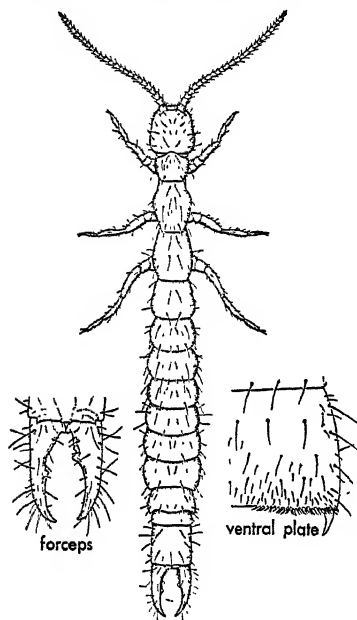


FIG. 30. *Iapyx diversiungus* Silvestri, a well-known North American species.

Family PROJAPYGDÆ Cook 1896 (Proja-pyg'i-dæ, see Iapygidæ below)
Projapygids.

Small blind insects intermediate between the CAMPODEIDÆ and the IAPYGDÆ. They are characterized by a pair of short, segmented cerci which differ from those of all other known members of the order in having glandular openings at the apices. At first they were thought to be immature forms of the IAPYGDÆ, which also have short, segmented cerci instead of pincers.

They comprise a small family of little-known distribution. Three genera and five species have been described from the Mediterranean region of southern Europe and northern Africa, Mexico, and South America. *Anajapyx vesiculosus* Silvestri has been carefully studied in Italy by Silvestri.

Family IAPYGDÆ Lubbock 1873 (JAPYGDÆ) (Ia-pyg'i-dæ, from the Greek 'ἰάπυξ, Iapygian, a native of southern Italy). Iapygids.

An odd family of primitive insects with fragile, slender, whitish bodies and a pair of rather short, unsegmented terminal forceps in place of the cerci usual to related families. Immature forms have short, segmented cerci which are replaced in the last molt by pincers. Although small insects, they are the largest members of the order. Their habits are similar to those of the campodeids, but they do not appear to be so common and numerous, at least in this country.

Approximately 15 genera and 100 species have been described from the following regions, listed in order of number of species: Palæarctic, Nearctic, Neotropical, Ethiopian, and Australasian. *Iapyx subterraneus* Packard, (*Japyx*), *I. americanus* MacGillivray, *I. diversiunguis* Silvestri are perhaps the best known

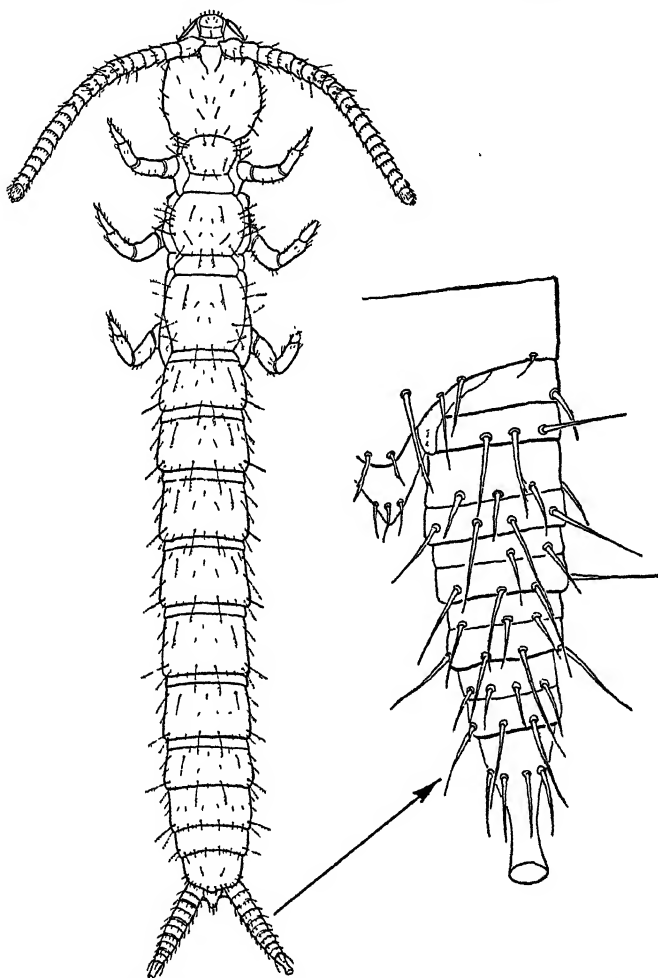


FIG. 31. *Anajapyx vesiculosus* Silvestri of Italy. (After Silvestri, 1907.)

North American species. The smaller species measure only six mm. whereas one of the largest species, *Heterojapyx souliei* (Bouvier), of Tibet, attains a length of 49 mm. None of our species appears to enter extensively into insect collections. They are collected and mounted according to the directions for the CAMPODEIDÆ.

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CHAPTER VII

4. Order COLLEMBOLA Lubbock 1870

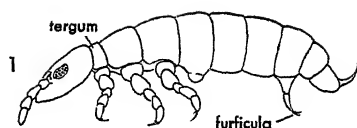
(Col-lem'bo-la, from the Greek κόλλα, glue, + ἐμβολον, wedge or peg; from the colophores or ventral tubes.) German, Springschwänze. French, Collemboles.

Springtails, Snowfleas.

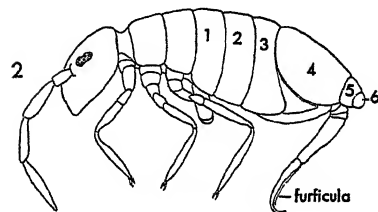
Very small to minute insects with primitive metamorphosis and biting mouth parts; body naked or clothed with scales or hair; antennæ four- to six-segmented; eyes present or absent, when present represented by no more than eight ommata on each side; tarsi and tibiæ usually fused; abdomen usually with a ventral tube, tenaculum, and spring on first, third, and fourth or fifth segments respectively (the tenaculum and spring are absent in some species).

The names springtails and snowfleas come from the springing abilities of most species and the fact that the adults often congregate in great numbers on the surface of the snow. They often also appear abundantly upon the surface of water during the fall, winter, and spring seasons. Most species inhabit wet or damp surroundings, living in moss, humus, caves, nests of termites and ants, and in various types of soils, under leaves, litter, or bark, or in similar places. A number of species are found in the intertidal areas along the seashores where they may be completely submerged for a considerable portion of the time. The order contains about 1,100 described species.

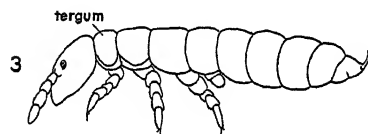
Their food consists chiefly of decayed vegetable matter, fungi, and lichens, but some species also eat spores, germinating



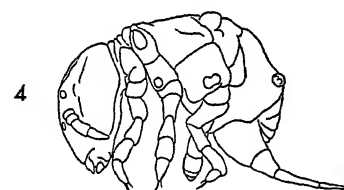
Achorutes californicus Bac



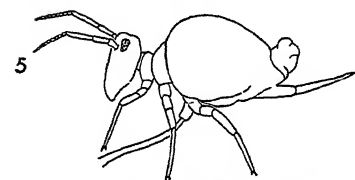
Entomobrya laguna Bacon



Onychiurus armatus Tullberg



Megalothorax minimus Willem
(Borner, 1906)



Smynthurus minnesotensis Guthrie
(Guthrie, 1903)

FIG. 32. COLLEMBOLA. Representatives of different families. (See text for key to sub-orders.)

seeds, and living plants to the extent of becoming injurious in greenhouses, gardens, and fields. Forms living on the surface of water feed extensively upon diatoms, desmids, algæ. Snowfleas also eat pollen grains as do certain of those that live on plants. Certain maritime species also feed upon carrion. A very few are predacious and cannibalistic. Several species have become beneficial because of their breeding in the filter beds of sewage disposal plants, where they act as scavengers and keep the sand clean and sharp.

Myrmecophilous and termitophilous species are blind and lack the springing organ or furca.

For the most part the biology of these insects has received little attention, and the habits and life histories of but a few species, including the lucerne flea, *Smythurus viridis* Linn., are recorded.

The known eggs are smooth or hairy and are laid singly or in groups of from five to 100 in soil, humus, manure, under bark, leaves, stones; in rotten wood; and similar places.

Nine genera and 12 species have been found in amber.

Collecting, Preservation, and Mounting. — Springtails are readily collected by hand by means of a small brush, or, much more effectively, with a bulb or mouth pipette bottle. The use of a large Berlese funnel is of great value for making careful collections and population studies. Leaves, soil, and refuse submerged or washed in water in a container will also liberate the springtails, which float on the surface.

They may be indefinitely preserved in 70 to 90 per cent alcohol, cleared in KOH, lactic acid, or other clearing agent, and mounted into balsam or euparal. Fresh specimens may also be mounted directly in Berlese or chloral hydrate media and are greatly improved by heating at 120° F. for 1 hr. If dried and ringed, such mounts will keep for many years.

ANATOMICAL CHARACTERS

<i>External</i>	<i>Internal</i>
<p>Size — minute to very small.</p> <p>Shape — slender to, almost globular.</p> <p>Exoskeleton — soft, smooth or granular cuticle often with scales, rods, or hairs. Sometimes with circular pseudocelli on the surface in the ONYCHIURINÆ.</p> <p>Color — white, drab, or slate to bright metallic hues.</p> <p>Head — prognathous or hypognathous.</p> <p>Eyes — compound eyes absent or represented by a group of eight or fewer ommata. True ocelli absent.</p> <p>Antennæ — usually four-segmented, rarely five- or six-segmented. Sense organs on segments III and IV.</p>	<p>Digestive System. Simple.</p> <p><i>Alimentary canal</i> — straight tube with extensive mid-intestine divided into four chambers in NEELIDÆ.</p> <p><i>Salivary glands</i> — present.</p> <p><i>Malpighian tubes</i> — absent. Excretion through the fat body and the epithelium of the stomach. In the latter case the waste materials are voided at the time of molting.</p> <p>Circulatory System.</p> <p>Heart composed of a series of six chambers with paired lateral ostia and anteriorly prolonged into the aorta, which may surround the fore intestine in <i>Anurida</i>.</p>

ANATOMICAL CHARACTERS—*Continued*

External	Internal
<p>Head—<i>continued</i></p> <p><i>Mouth parts</i> — for chewing or sucking. Withdrawn into the head.</p> <p><i>Mandibles</i> — slender, with separate molar and incisor areas.</p> <p><i>Maxillæ</i> — often complex with palpi absent or each represented by a seta.</p> <p><i>Labium</i> — greatly reduced.</p> <p><i>Hypopharynx</i> — whole or divided and with paragnaths or maxillulæ.</p> <p><i>Special sense organs</i> — postantennal organs consisting of single circular swellings, or rings, rosettes, and complex structures.</p> <p><i>Sensory pegs or papillæ</i> — clubs, knobs, cones, pits, rods, or hairs on antennal segments III and IV.</p> <p>Thorax — three regions evident, mesonotum sometimes covers the poorly developed prothorax.</p> <p><i>Legs</i> — four distinct segments: coxa, trochanter, femur, tibio-tarsus. Ending in a pair of claws, known as unguis and unguiculus (the latter may be absent).</p> <p><i>Spiracles</i> — a pair between the head and thorax in some genera.</p> <p>Abdomen — six segments, distinct or fused. Segment I with a ventral bilobed tube or adhesive organ with pair of protrusible sacs. Segment III with hamula, tenaculum, retinaculum, or spring holder on venter. Segment IV or V with furcula: a pair of partially fused appendages attached to the venter for springing.</p> <p><i>Cerci</i> — absent.</p> <p><i>Genitalia</i> — Sexes similar, no genitalia. Genital opening on segment V. Anus on the sixth sternite.</p> <p>Anal appendages in most SMYNTHURIDÆ.</p>	<p>Respiratory System.</p> <p>Respiration through the cuticle in most cases. Tracheæ present in <i>Sminthurus</i>, <i>Smynthurides</i>, and <i>Actaletes</i> (Imms, 1934).</p> <p><i>Spiracles</i> — a single pair between the head and thorax in those with tracheæ.</p> <p>Nervous System.</p> <p>Suboesophageal and three thoracic ganglia with double connectives. Cerebral ganglia and ventral nerve cord with four ganglionic centers or with ganglia fused. No separate abdominal ganglia.</p> <p>Reproductive System. Sexes are similar. Germarium in both sexes lateral rather than apical.</p> <p><i>Female</i> — a pair of sacs with short ducts which unite to form the vagina or ejaculatory canal. Ovaries composed of groups of vitelligenous cells and developing eggs.</p>

Springtails occur throughout the entire world from the Arctic to the Antarctic regions and are most abundant in the cooler temperate zones.

There are considerable differences of opinion as to the classification of the various members of the order. That of Handlirsch (1925), used herein, segregates the 1,200 described species into three suborders, five families, and about 100 genera.

KEY TO SUBORDERS

1. Body segments distinctly defined; last two or three segments partially fused. Body more or less extended. Head horizontal, seldom somewhat bent; antennæ situated in the distal half. Small tracheæ. Often scales on body. Furca frequently reduced. **ARTHROPLEONA**
2. Body compact, the last two segments somewhat separated; head vertical; antennæ situated in the middle. Head tracheæ with stigmas present. Without scales. Furca large. . . . **ACTALETOIDEA** p. 83
3. Body more or less spherical in shape; last two segments complexly blended or fused and with the extreme apical segment truncate. Head vertical; antennæ situated in or above the middle or rarely in front of middle. Head tracheæ usually present. Scales small. Furca large. . . . **SYMPHYPLEONA** p. 84

Suborder **ARTHROPLEONA** Börner 1901

(Ar'thro-ple'o-na, from the Greek ἄρθρον, joint, + πλεῖν, to swim; in CRUSTACEA the abdomen; referring to the jointed abdomen.)

KEY TO FAMILIES

1. Prothorax bare dorsally, usually membranous and somewhat covered by the mesonotum. Integument smooth or rarely finely granulate and covered with hairs or scales. Furcula present except in a few cases. . . . **ENTOMOBRYIDÆ** p. 82
2. Prothorax with dorsal bristles, free, not differing from other segments in texture. Integument granulate or tuberculate and without scales. Furcula present or absent. . . . **PODURIDÆ**

Family PODURIDÆ Lubbock, 1870 (Po-du'ri-dæ [Po-du'ri-de], from the Greek ποῖς, ποδός, foot, + οὐρά, tail; in reference to the springing organ or furca). Springtails, Snowfleas.

These are the common springtails and snowfleas, which are widely distributed and often exceedingly abundant. The immature forms live a secluded life and are often white or colorless whereas the adults, which appear above ground or on the surface of snow and water, are pigmented and often brightly colored. Some of the members of this family are injurious to germinating seeds and tender young plants while others are beneficial scavengers.

The family is composed of some 35 genera with 315 species distributed as follows:

Palæarctic 210, Nearctic 65, South American 30, African 10, Indo-Malaysian 15, Australian 20.

The most important genera are: *Achorutes* Templ., *Anurida* Lab., *Friesea* D. T., *Hypogastrura* Bourl., *Neanura* Macg., *Odontella* Schöff., *Onychiurus*

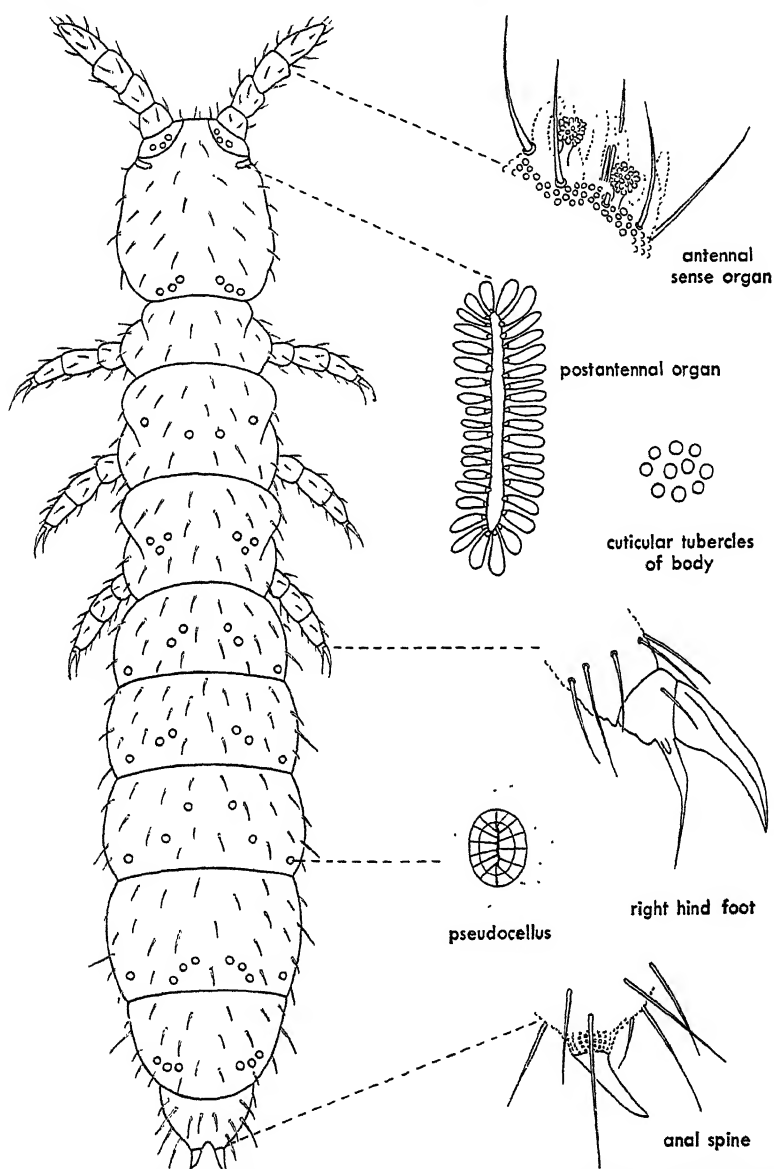


FIG. 33. The armed springtail, *Achorutes armatus* Nicolet, and important anatomical features. (After Folsom, 1917.)

Grev., *Podura* Linn., *Pseudachorutes* Tullb., *Tullbergia* Lubbock, and *Xenylla* Tullb.

The New Zealand *Holacanthella spinosa* Lubbock, a dull, slaty, spiny species 10 mm. long, is said to be the largest member of the order.

The armed springtail, *Achorutes armatus* (Nicolet), is probably the most widely distributed species in the world, being cosmopolitan in the temperate regions. The young are white and the adults slate-colored. They occur in the soil, among leaves, in rotten wood, manure, and similar places and often congregate in great numbers. They may devour germinating seeds and are at times a pest to mushrooms.

The snowflea, *Achorutes nivicolus* Fitch, is a dark blue-black cosmopolitan species often occurring on the surface of snow.

The seashore springtails, *Anurida maritima* Lab. and *Xenylla maritima* Tullb., are common and often very abundant along the seashores of Europe and Africa and the latter has also been noted in North America. They feed on dead animal matter and debris.

The golden snowflea, *Onychiurus cocklei* (Folsom), is a minute yellow species which often appears in great numbers on the surface of the snow along the Pacific coast from British Columbia into Alaska.

The water springtail, *Podura aquatica* Linn., is widespread in Europe and North America and frequently occurs in myriads on the surface of standing fresh water.

Family ENTOMOBRYIDÆ Tömösvary 1883 (En'to-mo-bry'-i-dæ, from the Greek *ἐντομον*, insect, + *βρύον*, moss; in reference to the damp habitats of some species).

This is the dominant family of the order. The body is somewhat cylindrical with smooth cuticle clothed with scales and simple, clavate, and pectinate hairs. The furca arises from the fourth abdominal segment and is long in certain species. The antennæ are normally four-segmented, but those of the genus *Orchesella* have six segments.

According to Handlirsch (1925) there are approximately 50 genera and 560 species distributed as follows: Palearctic 226, North American 96, South American 54, African 29, Indo-Malaysian 72, and Australian 45.

The important genera are *Anurophorus* Nicolet, *Cyphodurus* Nicolet, *Entomobrya* Rondani, *Folsomia* Willem, *Heteromurus* Wankel, *Isotoma* Bourlet, *Isotomurus* Börner, *Lepidocyrtus* Bourlet, *Lepidophorella* Schäffer, *Orchesella* Templeton, *Paronella* Schött, *Proisotoma* Börner, *Sinella* Brook, *Sira* Lubbock, and *Tomocerus* Nicolet. The most important of these are *Entomobrya*, *Isotoma*, and *Tomocerus*.

The marsh springtail, *Isotoma palustris* (Müller), is widely distributed through northern Asia, Europe, and North America. It lives under wet leaves and in wet soil and moss and may also appear on the surface of fresh-water pools. *Isotoma viridis* (Bourlet), a green species, attaining a length of from 5-6 mm., occurs in Europe and North America. *Salina wolcottii* Folsom is a

small, yellowish-green species that often occurs in immense numbers on the undersides of leaves of sugar cane in Porto Rico. It scarifies the leaf tissues and is an important cause of the mosaic ring-spot disease.

Suborder ACTALETOIDEA Schröder 1925

(Ac'ta-le-toi'de-a, from the Greek ἀκτή, promontory, sea-shore; from the habitat.)

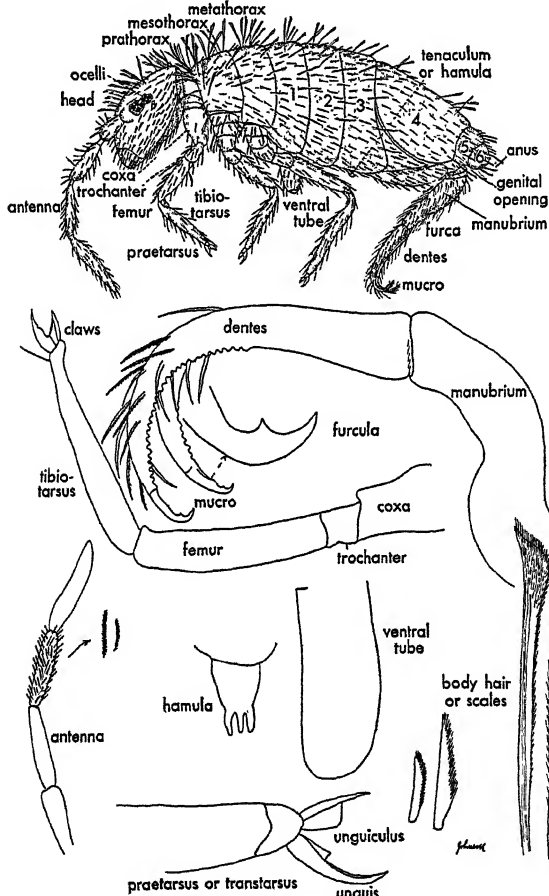


FIG. 34. The Laguna springtail, *Entomobrya laguna* Bacon, a seashore species of southwestern North America.

Family ACTALETIDÆ Handlirsch 1925.

A very small family with a single genus, *Actaletes* Giard, of France. The body is without scales and has a large furca.

Suborder SYMPHYPLEONA¹ Börner 1901

(Sym'phy-ple'o-na, from the Greek *συνήϋς*, grown together, naturally united, compact, + *πᾶν*, the abdomen; referring to their compact bodies.)

KEY TO FAMILIES

1. Coxæ longer than trochanters; antennæ stout, not longer than the head, last segment short and undivided; thorax longer than abdomen **NEELIDÆ**
2. Coxæ not longer than trochanters; antennæ normal, longer than the head, last segment long and marked into ring joints; thorax not so long as the abdomen **SMYNTHURIDÆ**

Family NEELIDÆ² Folsom 1896 (Ne-el'i-dæ, from the Greek *νέηλος*, a new-comer).

A small family of minute, globular, bristly species with very short antennæ inserted on the middle or front of the head, with eyes present or (rarely) absent, and with the furca about twice the length of the antennæ. They live under dead bark and in wet, decaying vegetation. The two genera *Neelus* Folsom and *Megalothorax* Willem and four species are holarctic.

Family SMYNTHURIDÆ Lubbock 1870 (Smynthur'i-dæ, from the Greek *σμύνθος*, mouse, + *οὐρά*, a tail; referring to the furca).

More or less globular species, usually with the head vertical; the antennæ inserted on the back portion of the head; eyes usually present; the legs long; the coxæ and trochanters equal or the former shorter; and the furca on the fifth abdominal segment.

These springtails jump very friskily and often occur in immense numbers in moist or wet places on the surface of the soil or water or feeding upon living plants. There are, according to Handlirsch (1925), 13 genera and 200 species distributed as follows: 109 Palæarctic, 47 North American, 18 South American, seven African, six Indo-Malaysian, and six Australian. Some additional species have been described since these estimates were made in 1925. The important genera are: *Bourletiella* Banks, *Sminthides* Börner, *Sminthurinus* Börner, *Sminthurus* Latreille, *Dicyrtoma* Bourlet (*Papirius* Lubbock), and *Corynephorina* Absolon.

The garden springtail, *Bourletiella hortensis* (Fitch) (*Sminthurus*), and the yellow springtail, *B. lutea* (Lubbock), feed upon weeds, flowers, vegetables, and field crops in northern Europe and eastern United States and may do considerable damage. The former is also known in South America and Japan.

The lucerne flea, *Sminthurus viridis* Lubbock, is a bright-green species often very abundant in the fields and meadows of northern Europe, Australia, and

¹ SMYNTHUROIDEA Crampton 1920.

² MEGALOTHORACIDÆ Börner 1874 is a synonym.

Tasmania, and may also attack cultivated plants, being particularly injurious to alfalfa or lucerne, clover, and other legumes (Davidson, 1934).

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CHAPTER VIII

5. Order ORTHOPTERA Olivier 1789¹

(Or-thop'ter-a, from Greek ὀρθός, straight, + πτερά, wings.)

Locusts, Grasshoppers, Katydid, Crickets, Mole Crickets.

Medium-sized to large insects, usually with a pair of narrow leathery fore wings or tegmina and a pair of well-developed membranous hind wings which fold longitudinally and are covered by the tegmina when at rest. Many are brachypterous or apterous. They have strong biting mouth parts; compound eyes; usually two or three ocelli or none; short or long, simple or segmented cerci; and simple metamorphosis.

This very important and destructive order numbers about 12,000 species, distributed generally throughout the entire world with the exception of the polar regions. The members are peculiar in that the vast majority of species are saltatorial and have the hind legs developed for jumping. Certain species on every continent migrate in immense hordes and devastate great areas of native and cultivated plants. Since the dawn of civilization locusts have harassed every human race, destroying crops and causing suffering and death by famine. For this reason they appear among the earliest records of antiquity.

They are for the most part ground-living insects, a number being subterranean and many arboreal. Their food is almost wholly vegetation, which they consume in quantities. A very few forms are partly or wholly predacious on other insects and other animals of like size, while even the vegetarian types become cannibalistic in the absence of normal food. Certain species of crickets and grouse locusts live near water and swim readily and even dive, but the average orthopteran that ventures into the water is soon destroyed by fishes, as every country boy knows.

Palæontologically the members of this order may be traced through certain related ancestors back to the carboniferous period.

External anatomy. — Structurally these orthopterans are peculiarly different from all other insects. Yet it is possible to point out certain characteristics only by specimens or by illustrations. The adults are decidedly elongated and more or less cylindrical in form although many are compressed, others depressed, and still others quite robust. The exoskeleton is tough and leathery and often protected by the folded tegmina and wings. The sutures separating the many body parts are of considerable value in classification. The head is set into the prothorax; the face is vertical and the mouth ventral. The antennæ are often conspicuously long, filiform, and many-segmented, the compound eyes large and

¹ The name ORTHOPTERA was first applied to this group and related forms by Olivier in 1789 and more appropriately restricted in its use by Latreille in 1796 who later also designated them as SALTATORIA in 1817. For years it was a loosely interpreted group which only recently has been restricted to more homogeneous forms.

usually supplemented by two or three ocelli. The prothorax is rather large and always prominent. The fore and middle pairs of legs are small and are used for crawling, climbing, alighting, and clinging, while the greatly modified hind legs

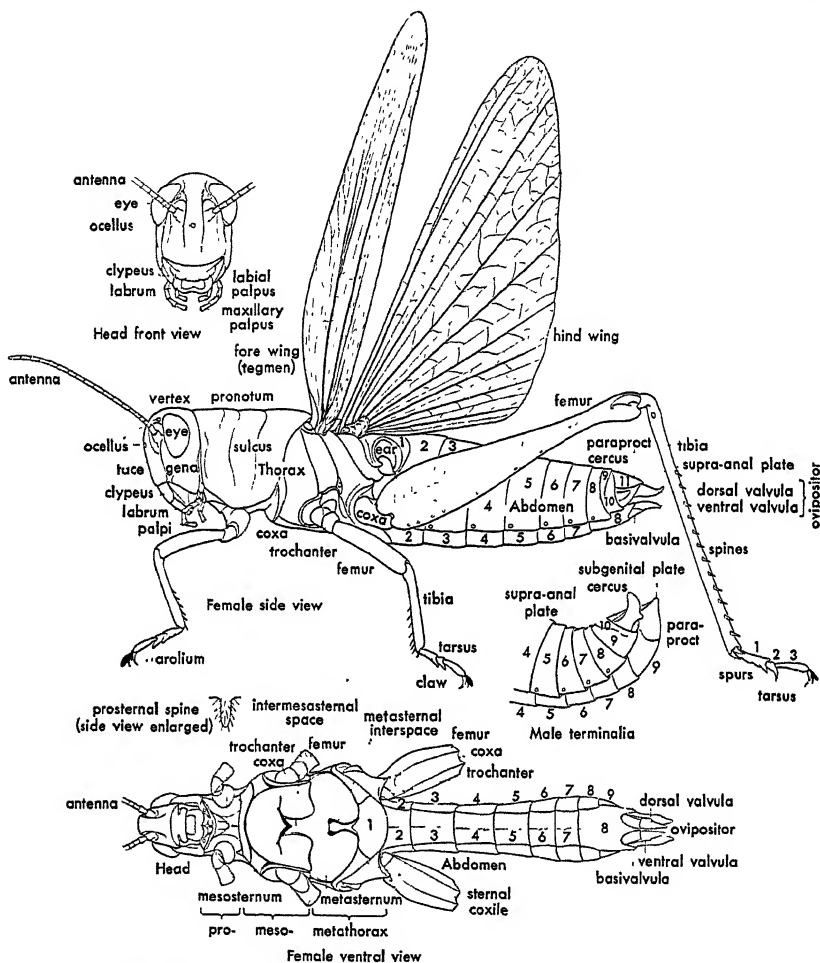


FIG. 35. Drawings of the differential grasshopper, *Melanoplus differentialis* (Thomas), showing important external features.

are employed to catapult the body forward in violent jumps. The animal frequently makes hard landings head first without apparent discomfort. Only a tough and elastic frame could stand such shocks. The abdomen is normally composed of 11 segments, of which the first 10 are evident and the 11th is vestigial. In certain members, as the mole crickets, only the eighth and ninth seg-

ments are visible. Often the ninth sternum of the male bears a pair of anal styli. There are two thoracic and eight abdominal pairs of spiracles. The females of the locusts, grasshoppers, sand crickets, and mole crickets have inconspicuous ovipositors, while the katydids, crickets, cave crickets, and tree crickets have prominent sword-like, sickle-shaped, or spear-shaped ovipositors which make them easily recognizable and serve to place the eggs in the soil or into the tissues of leaves, stems, or limbs of plants. Long or short simple or jointed cerci are also present at the tip of the abdomen.

The stridulating or sound-producing organs and auditory organs of this order are quite highly developed and rather unusual among insects. They are more fully discussed under the various families.

The coloration is normally cryptic, matching or mimicking the immediate surroundings. The ground-inhabiting forms are usually various shades of gray, drab, brown, yellow, or black. Grass- and plant-feeding species are frequently green or various combinations of bright colors. The hind wings are also frequently bright red, yellow, orange, blue, or even black. Nocturnal forms, like the common field crickets, are black or brown, although nocturnal cave and camel crickets may be of combinations of very pale colors.

Internal anatomy. — These typically biting, herbivorous insects have strong mouth parts and naturally a well-developed digestive system in which the oesophagus expands into an ample crop leading into a specialized type of gizzard (wanting or vestigial in the LOCUSTIDÆ). The mid-intestine is long and convoluted in the TETTIGONIIDÆ and GRYLLIDÆ and straight with longitudinal plait in the LOCUSTIDÆ. There are six enteric cæca, each with a short posterior diverticulum, in the LOCUSTIDÆ and two sac-like cæca in the TETTIGONIIDÆ and the GRYLLIDÆ. The Malpighian tubules are arranged in bundles in the LOCUSTIDÆ, capillary and opening in groups at the tops of small papillæ in the TETTIGONIIDÆ, and in a single bundle discharging into the common duct in the GRYLLIDÆ.

The nerve centers consist of three thoracic and normally five or six and rarely four abdominal ganglia. In some of the locusts the tracheal system has a series of air sacs of which a large pair is located in the thorax and five pairs in the abdomen. The reproductive organs are far too variable to be adequately treated here, and the reader is referred to works on anatomy for this information.

Practically all species are oviparous, but the shape and structure of the eggs and the manner and place of their deposition is exceedingly varied and are discussed under the families, as are also the more generalized types of life histories and habits. There are about 21,000 species in this group, including those of the orders BLATTARIA, PHASMIDA, MANTODEA, and other orthopteroid groups.

KEY TO SUBORDERS

1. Antennæ setiform, short, usually much shorter than the body; auditory organ, when present, near the base of the abdomen and often partially or wholly covered by the base of the wings; ovipositor incon-

The members of this family are among the best known insects and are familiar to almost every savage or civilized person. As a matter of fact, grasshoppers and locusts have always been an important item of the diet of all aboriginal peoples and are still consumed in considerable quantities in many parts of the world. The term grasshopper is now generally restricted to the common nonmigratory forms while the name "locust"¹ is reserved for those migratory wanderers which have proved so destructive throughout all time. In Biblical times the Hebrews referred to these insects under nine different names, each of which signified destruction. Every large land mass, excepting only the frigid zones, has its particular kind or kinds of migratory locusts and the problems arising from them. Many species of grasshoppers are also quite destructive.

Aside from their economic significance these insects are most interesting to collect and study. As will be seen from the keys they are frequently referred to as short-horned grasshoppers because the antennæ rarely attain half the length of the body. The head is somewhat sunk into the prothorax and has, besides the large compound eyes, three small ocelli. The prosternum in many species has a short peg-like process between the coxæ of the forelegs. The fore- and middle legs are small as compared with the hind legs in which the femora are greatly thickened and the tibiæ long and armed with two rows of spines. These hind legs serve admirably as a means of ground locomotion and to take off in flight. Both the tegmina and membranous wings are used in flight. The latter are often brightly colored. In certain species the rubbing of the costal margins of the wings against the thickened veins of the tegmina in flight produces a loud startling crackling noise. A dull-gray species, with beautiful pale blue underwings, *Circotettix thalassinus* Saussure, common in the high Sierras of California, is called the firecracker grasshopper because of its sound-making abilities. Some grasshoppers stridulate by rubbing a keel-like ridge, or rarely a series of 80 or 90 small pegs, situated along the inner surface of the hind femora, against a raised vein on the thickened basal areas of the radius of the tegmina. They are thus able to produce characteristic noises often referred to as fiddling. Even the young may be observed going through the motions of fiddling though they have no wings across which to draw the rasping femora. An auditory organ, consisting of a tympanum variously designed, usually occurs in both sexes on either side of the abdomen under the bases of the folded wings.

These insects have a simple type of development. The female normally deposits the eggs in the soil. She drills a hole with the tip of the abdomen as deep as that elastic part of the body will permit and deposits from 20 to 100 elongated eggs in a matrix of a cement-like secretion within the hole. Thus the egg mass may often be removed in its entirety and is frequently referred to as an egg sac, egg flask, and egg packet. As many as 20 egg masses may be deposited by a single female. In the cooler temperate regions the eggs are laid only in late summer and fall and constitute the only hibernating stage, but in the subtropical and tropical regions living forms may occur throughout the entire year and

¹ The term "locust" is also unfortunately applied to the 17-year cicada or harvest fly as well as to certain American trees.

eggs may be deposited from two to four times a year. The young outwardly differ from the adults only by the smaller size, variation in color, and absence of wings although many forms are wingless throughout their entire existence. After five to eight ecdyses the adult stage is reached. There is usually only one generation a year, but certain tropical species have two. Reasons for migrations are not clearly known but it appears that only certain types of individuals within a species known as the "swarming phase" make these great flights while those which do not migrate are called the "solitary phase." The most important migratory locusts are:

EURASIA, NORTHERN AFRICA, OCEANIA

The desert locust, *Schistocerca gregaria* Forskål (*S. peregrina* Olivier, *S. tatarica* Linnæus), has a yellow, nonmigratory phase and a pinkish, migratory phase, both marked with small dusky patches on the tegmina. It is 2 in. or over in length. It breeds in sand hills with sparse vegetation and is believed to be the locust often mentioned in ancient writings as causing the plagues of Egypt, northern Africa, Arabia, Persia, Afghanistan, northern India, and the islands of the Mediterranean. It flies long distances and has been found 1,200 miles at sea. In 1881 in Cyprus 1,600,000,000 egg cases, or 1,300 tons of eggs, were destroyed, and in 1883 it was estimated that nearly four times as many eggs were deposited in the soil of the island. In the Sudan in 1930, 1,100 tons of poison baits were used to stay its ravages.

The migratory locust, *Locusta migratoria* Linnæus (*L. migratorioides* Reiche and Fairmaire, *L. danica* Linnæus), is yellowish or grayish-green and about 2 in. long. It occurs in most of Europe, Africa, Asia, Oceania, northern Australia, New Zealand, and Madagascar. It breeds in dry grassy places next to jungles and swamps, in burnt-off places, and in other areas of sparse vegetation and is often a very serious pest. The Bombay locust, *Cyrtacanthacris succincta* (Linnæus) (*Acrydium*), is a reddish species similar to the migratory locust which often occurs in immense swarms in India.

The Moroccan locust, *Dociostaurus moroccanus* Thunberg, is pale grayish-brown with black spots and averages about 1 in. in length. It occurs throughout the Mediterranean region and ranges east into northern Persia and Turkestan. It breeds in hilly or mountainous regions.

The Italian locust, *Calliptamus italicus* (Linnæus), is dark brown, yellowish-brown, or grayish, often with small gray or brown spots on the tegmina, and is about 1 in. long. It breeds extensively in sage-brush steppes and in the loose dry soils of areas of sparse vegetation and occurs within about the same range as the Moroccan locust.

SOUTH AFRICA

The brown locust, *Locustana pardalina* (Walker), is yellowish-gray with small brownish spots on the tegmina, and nearly 2 in. long. It breeds in the desert grass lands of interior South Africa and may migrate to the coasts. There may be two or more generations a year.

The red locust, *Nomadacris septemfasciata* Serville, is reddish-brown or brown with a pale dorsal stripe and several brownish oblique parallel fasciæ on the tegmina. It is 2 in. or over in length, and, while its exact breeding places are unknown, it often appears in immense destructive numbers throughout the whole of South Africa.

SOUTH AMERICA

The South American locust, *Schistocerca paranensis* Burmeister, is grayish-white with large black spots on the tegmina, and 2 in. or over in length. The eggs are laid in the spring in soft, damp soil and hatch soon afterwards. The adult stage is attained by the end of the summer. After hibernation, migration and egg laying occur the next spring. This species occurs throughout the entire continent and ranges as far north as Mexico, but appears to be most destructive in northern Argentina where it is often very abundant.

NORTH AMERICA

The Rocky Mountain locust, *Melanoplus spretus* (Uhler), which was described as a small yellowish-brown species with minute dark spots on the wings and about $1\frac{1}{2}$ in. long, bred in great numbers in the prairies of the eastern slopes of the Rocky Mountains in the United States and did great damage to wheat, corn, and other crops in the Middle West in 1873 and for many years afterwards. This visitation is now generally ascribed to phases of the lesser migratory locust, *Melanoplus mexicanus atlantis* (Riley), and the red-legged locust, *Melanoplus femur-rubrum* DeGeer. In recent years the two-striped locust, *Melanoplus bivittatus* (Say), has been an important species in corn and wheat fields of the Middle West.

In the interior valley regions of northern and central California a similar species, the devastating locust, *Melanoplus devastator* Scudder, did considerable damage up until the year 1914.

Family TETTIGIDÆ Walker 1870 (Tet-tig'i-dæ, from the Greek τέττιξ, a kind of grasshopper, or the cicada). Grouse Locusts, Pigmy Locusts.

The members of this family are the smallest and most peculiar of the short-horned grasshoppers. They are scarcely more than 15 mm. long, are somewhat robust in appearance, and have a prolonged and tapering pronotum which extends backwards to or beyond the tip of the abdomen. The prosternum is also extended forward as a chin-plate so as to cover the mouth. The tegmina are represented by small scale-like plates at the bases of the wings, which are well developed. The legs are short, the hind femora being greatly enlarged for jumping; the fore and middle tarsi are two-segmented and the hind tarsi are three-segmented; the arolia and stridulating and auditory organs are absent.

These extremely active locusts are vegetarians feeding on fungi, algæ, mosses, lichens, grasses, seeds, various other plants, and decayed vegetable matter. They occur in rather arid or in wet localities. Species living around water swim

and dive with alacrity. They are colored to match their surroundings and are often extremely difficult to see. The adults hibernate and lay their eggs in the soil in the spring.

The family is widely distributed. There are some 100 genera and 650 species. Two thirds of the species are tropical. The greatest number occurs in the Indo-Malaysian, Oceanic, and Ethiopian regions. There are some 210 species in the Americas.

Among the common world species are: *Acrydium subulatum* (Linnæus), *A. depressum* (Brisout), *A. bipunctatum* (Linnæus), of Europe, northern Africa, and western Asia; the ornate grouse locust, *A. ornatum* Say, and the granulated grouse locust, *A. granulatum* (Kirby), in North America, the latter limited to Canada and northern United States; the Aztec grouse locust, *Telmatettix aztecus* (Saussure), in southwestern United States, Mexico, and Cuba; *Paratettix meridionalis* (Rambur) in southern Europe, northern Africa, western Asia, and Madagascar; the hooded grouse locust, *P. cucullatus* (Burmeister), in Canada and the United States; the Toltec grouse locust, *P. toltecus* (Saussure), in southern United States, Mexico, and Central America; and the black-sided grouse locust, *Tettigidea lateralis* (Say), in North America.

Suborder TETTIGONIODEA Karny 1903

(Tet'ti-gon'-o'-de-a, from the Greek τέττιξ, τέττιγος a kind of grasshopper, the cicada.)

KEY TO PRINCIPAL FAMILIES

1. Tarsi normally four-segmented; body somewhat compressed or cylindrical and robust; ovipositor, when apparent, sword-shaped or sickle-shaped 2
- Tarsi normally three-segmented or less (in TRIDACTYLIDÆ); body often appears somewhat depressed; ovipositor, when apparent, spear-shaped or awl-shaped. 3
2. Ovipositor usually conspicuous, sword-shaped or sickle-shaped; body usually somewhat compressed; auditory organ often present on the fore tibiæ; winged and apterous forms. (Katydids.)
- (LOCUSTIDÆ) TETTIGONIIDÆ p. 95
- Ovipositor inconspicuous; body usually robust; auditory organ not present on fore tibiæ; wholly apterous or with partially developed wings. (Sand Crickets, Camel Crickets.)
- STENOPELMATIDÆ p. 98
3. Fore tibiæ normal, usually with an auditory organ on each side; ovipositor well developed and spear-shaped or awl-shaped. (Crickets, Tree Crickets, Ant Crickets.)
- GRYLLIDÆ p. 99
- Fore tibiæ greatly enlarged or fossorial; ovipositor not exposed. 4
4. Antennæ filiform, many-segmented; two large ocelli present; tarsi three-segmented; hind femora not enlarged for jumping; large insects 18 mm. long or over, densely clothed with short hairs; burrow in the soil. (Mole Crickets, Changa.)
- GRYLLOTALPIDÆ p. 102
5. Antennæ short, 12-segmented or less; three small ocelli present; fore and middle tarsi two-segmented, hind tarsi one-segmented or obsolete;

very small insects less than 10 mm. long, with smooth bodies and greatly developed hind femora for jumping. (Sand Crickets, Pigmy Mole Crickets.)

TRIDACTYLIDÆ p. 103

Family TETTIGONIIDÆ Karny 1903 (LOCUSTIDÆ Burmeister 1838) (Tet'ti-gon-i'i-dæ, from Greek τέττιξ, a kind of grasshopper). Long-horned Grasshoppers, Katydid, Meadow Grasshoppers.

Some confusion now exists in connection with the proper usages of the family names TETTIGONIIDÆ and LOCUSTIDÆ. During past years the latter term was used almost exclusively for the long-horned or angular-winged grasshoppers or katydids, but in very recent times this name has more appropriately been used for the true locusts and grasshoppers and TETTIGONIIDÆ substituted as above. If the student can keep this change in mind, much confusion will be avoided. Certain members formerly placed in with the katydids are now relegated to the STENOPELMATIDÆ, a very closely related family.

These insects are commonly known as green grasshoppers, long-horned grasshoppers, angular-winged grasshoppers, meadow grasshoppers, and katydids. The name "katydid" has gradually replaced all others. It originated in the United States, having been derived from characteristic stridulatory sounds produced by the males of certain green species, notably *Pterophylla camellifolia* (Fabricius) (*Platyphyllum concavum* Harris), whose note, the loudest of all species

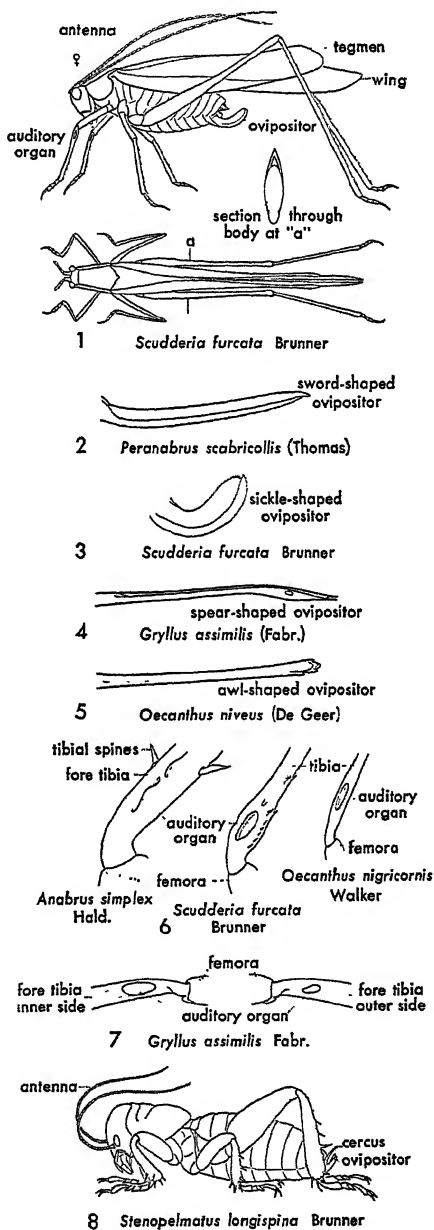


FIG. 37. Important characters of the TETTIGONIOIDEA.

of the eastern states, simulates "Katy did, Katy she did." The notes begin soon after dusk, are uttered at intervals of about 5 seconds, and may continue until daybreak. Our western species stridulate audibly but make no such remarks, and this appears to be equally true in most other parts of the temperate and tropical world wherever these insects live. There are some 1,120 known genera and over 7,000 described species.

The tree-inhabiting forms are commonly green to match their immediate surroundings, often with the tegmen remarkably leaf-like in design and color. The wingless, ground-inhabiting forms are usually dull in color, normally entirely wingless or with very short wing stubs. The compressed bodies, the extremely long and many-segmented antennæ, the four-segmented tarsi, and the greatly developed sword-shaped or sickle-like ovipositors serve most readily to distinguish them. The hind legs are very long and fitted for jumping. The flight is short and rapid. While they are mostly diurnal, many sing during dusk and the early part of the night while other species often keep up their ceaseless repetitions throughout the whole summer night and in most places they are commonly mistaken for crickets. In all cases the noises are produced by rubbing together a file at the base of the left tegmen and a scraper on the right. Many of the so-called wingless katydids in reality have very short tegmina, often hidden by the large pronotum and so constructed as to be excellent musical instruments. Females may also stridulate but are not so noisy as the males. Auditory organs occur as tympanums exposed or hidden on the outer bases of the fore tibiae.

Katydids are largely herbivorous and feed upon native trees, shrubs, grasses, and cultivated plants. Some forms, however, are supposed to be carnivorous as is the case with many of the members of the entire order ORTHOPTERA. By means of the large ovipositors the eggs are deposited into the soil or into the tissues of plants. Some insert their large reniform flattened eggs in the edges of leaves and in confinement have slit the edge of ordinary writing paper to insert perfectly an egg three or four times as thick as the paper. In the temperate regions the eggs alone remain over winter and each year a new generation appears, only to die out before the succeeding winter.

Among the more interesting arboreal forms may be mentioned the following species: In middle and eastern North America the northern katydid, *Pterophylla camellifolia* (Fabricius), already mentioned, is by far the best known because of its shrill characteristic notes. It measures from 25–35 mm. in length and is generally dark green tinged with yellow. The eggs are inserted into the crevices of the loose bark of trees. The Florida katydid, *Lea floridensis* (Beutenmüller), is a pale yellowish-green species common in the oaks and cabbage palms of Florida.

Among the narrow-winged katydids, *Scudderia furcata* Brunner is most widely distributed in this country, ranging from southern Canada to Florida and central California. The male stridulations sound like ch-h-e-ep, repeated four or five times at intervals of 1 second. It is diurnal and its song continues into the forepart of the night. The females lay their eggs in the edges of leaves,

using their front legs and mouth parts as aids in oviposition. Many other species of broad-winged and narrow-winged katydids occur in nearly every locality.

In the Old World the beautiful large green katydid, *Phasgonura viridissima* (Linnaeus), is well known in Europe, northern Africa, and western Asia.

Among the less conspicuous and usually wingless or brachypterous ground-inhabiting forms, perhaps the most famous is the western, Great Plains, or

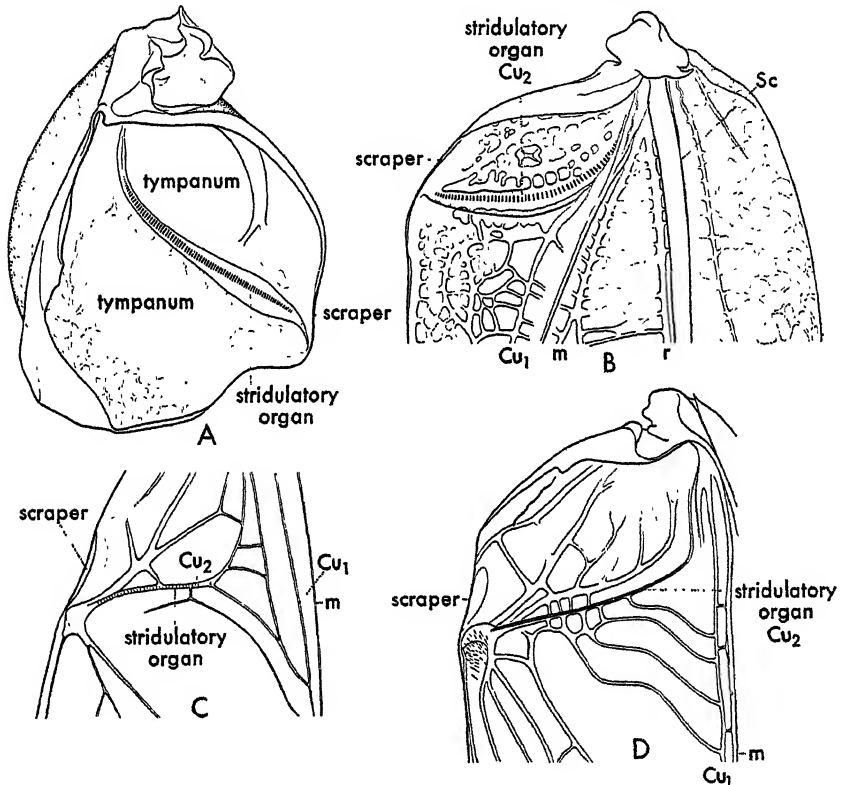


FIG. 38. Stridulatory scrapers or files on the bases of the tegmina of male katydids and crickets. A, a short-winged katydid or carinated shieldbearer, *Neduba carinata* Walker; B, fork-tailed katydid, *Scudderia furcata* Brunner; C, the snowy tree cricket, *Oecanthus niveus* (De Geer); D, the common black field and house cricket, *Gryllus assimilis* (Fab.).

Mormon cricket, *Anabrus simplex* Haldeman, a large wingless dark-brown or black species measuring from 35–45 mm. in length. It often swarms in the Great Basin region of the United States, where it has been responsible for extensive damage to cultivated, forage, and grain crops and to natural pasturage. A sally of sea gulls, which checked such an outbreak at Salt Lake City, Utah, in the pioneer days of that settlement, was responsible for the erection of the

famous sea-gull monument in that city. The coulee cricket, *Peranabrus scabricollis* (Thomas), is almost as serious a pest in the more arid regions of the Pacific Northwest. These species oviposit in the soil and, although wingless, they are able to travel considerable distances on foot.

In China the katydids *Gampsocleis inflata* Uvarov and *G. gratiosa infuscata* Uvarov are employed by the Chinese of Peking as musical insects. Crickets are, however, more often used for this purpose.

Family STENOPELMATIDÆ Burmeister 1838 (Sten'o-pel-mat'i-dæ, from the Greek στενός, narrow, + πέλμα, sole of the foot). Sand Crickets, Camel Crickets, Cave Crickets, Jerusalem Crickets, and Wetas.

This family is not clearly defined at the present time but includes five subfamilies, 61 genera, and about 300 species. They are rather robust, usually wingless, but may be brachypterous or, rarely, winged. The antennæ are often very long and filiform and may be four or five times as long as the body; the hind tibiæ are heavily spurred; the tarsi four-segmented and usually compressed or flattened but rarely narrow, as indicated by the scientific name. The cerci are short but conspicuous, and the ovipositor is obscure in the sand crickets and short or prominent in the other forms. They are mostly fairly large insects, and the color is usually various shades of brown or gray. They are largely carnivorous although some species are at least partly vegetarians. They live in caves, in cracks and holes in the ground, or in and under masses of dead and decaying leaves and other vegetation, under stones, in rock piles, hollow logs, and other similar wet, damp, or dry places of concealment. These insects are mostly nocturnal in habits although some species are commonly taken during the day. Most species are without stridulating or auditory organs. They have no great economic importance.

The cave and camel crickets occur throughout the world but are most numerous in species in North America. The genus *Ceuthophilus* is a large one in North America with species obtainable in almost every state. A Japanese species, *Diestrammena japonica* Blatchley (*D. marmorata* Haän), has been widely distributed in greenhouses in the United States. The sand crickets of the genus *Stenopelmatus*, limited to the western and southern parts of North America, are most remarkable and aggressive-looking insects. Certain Indian tribes of the Pacific coast looked upon them with almost human regard and refer to the insects in their folklore. The large Australian king cricket, *Anostostoma australasiz* Gray, is a brown apterous species 3 in. long. The male has an enormous head and huge projecting labium and mandibles. It occurs in eastern Australia. The giant weta or weta-punga, *Deinacrida heteracantha* White, an allied species of New Zealand, is a huge dull-brown wingless species, the body of which is 4 in. long. According to Tillyard, who figures it in *Insects of Australia and New Zealand*, 1926, it is now practically extinct.

Another remarkable species in the closely related family SCHIZODACTYLIDÆ occurs in India, where it is known as bherwa, *Schizodactylus monstrosus* Drury. It is a large species in which the tips of the tegmina are coiled, and the

tarsi have curious expansions. It burrows in sandy soil near streams and is believed to be carnivorous.

Family GRYLLIDÆ Saussure 1894 (Gryl'li-dæ, from the Greek γρύλλος, a pig, and the Latin *gryllus*, a cricket). Crickets, Tree Crickets.

This is one of the most interesting and well-known families of insects and is widely distributed throughout the world, there being six subfamilies, 64 genera, and about 1,150 described species. They greatly resemble the TETTIGONIIDÆ and certain of the STENOPELMATIDÆ in having long antennæ, exserted ovipositor, and auditory and stridulating organs. The auditory organs are located on both sides of the front tibiæ, and the stridulating organs consist of a file, a scraper, and a tympanum or vibratory area on each tegmen. In stridulating, the tegmina are elevated above the abdomen and vibrated rapidly so as to cause resonant sounds quite different from those produced by other insect musicians. The chirps and songs of the crickets constitute the major part of the ceaseless insect orchestration throughout the summer nights.

Crickets differ from their near relatives in having three-segmented tarsi, usually a flat dorsum and a spear- or awl-shaped ovipositor, long unjointed cerci, and short anal styli. They are winged or wingless and are, for the most part, ground-inhabiting.

They hide in holes in the ground or under stones and debris during the day, and move about after nightfall. However, when abundant and swarming they may appear both day and night. They are both herbivorous and carnivorous, and, under press of hunger in confinement, cannibalistic. The eggs are laid in the soil or, as in the case of tree crickets, inserted in rows in the branches or twigs of dead or living plants.

Every country has its black cricket. In North America, Central America, and the northern half of South America the field cricket, *Gryllus assimilis*

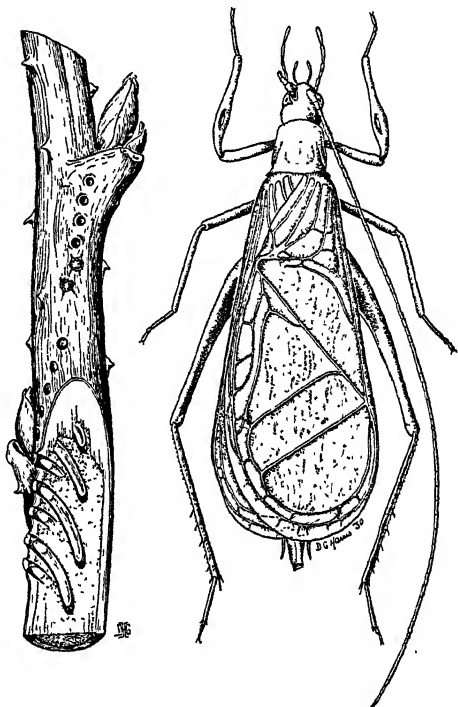


FIG. 39. The snowy tree cricket, *Eucanthus niveus* (De Geer). Egg-punctures, eggs exposed to view in a raspberry cane, and adult male. The males are among the most fascinating insect musicians. (After L. M. Smith.)

(Fabricius), a black species with brown wings, measuring about 20 mm. when fully grown, is the common species. In Europe, northern Africa, and western Asia, the house cricket, *Gryllus domesticus* Linnæus, is the "cricket on the hearth" of literature. *G. frontalis* Fieber is another common species in Germany, Austria, and southern Europe. The desert cricket, *G. desertus* Pallas, also occupies southern Europe, northern Africa, and western Asia. The Spanish cricket, *G. hispanicus* Rambur, is confined to the Spanish Peninsula, Madeira, the Canary Islands, and South Africa. The shell cricket, *G. testaceous* Walker, lives in China, Japan, India, Ceylon, Straits Settlements, and the Philippines. The Chinese cricket, *G. chinensis* Weber, has a much wider distribution that extends from China through southern Asia and southern Europe, Africa, and Madagascar. The Oceanic cricket, *G. oceanicus* Le Guillou, occurs in Japan, Borneo, the South Pacific Islands, and Hawaii.

Three other crickets might be mentioned: the shrill house cricket, *Brachytrypes megacephalus* Lefebure, inhabiting Sicily and North Africa, whose shrill note may be heard a mile; the European field cricket, *Liogryllus campestris* (Linnæus), of Europe, North Africa, and western Asia; and the two-spotted cricket, *Acheta bimaculata* (De Geer), of southern Europe, Asia, and Africa.

The Chinese and Japanese are very fond of singing crickets. They cage and make as much of these insects as other people do of songbirds. Male crickets are naturally pugnacious and fight freely among themselves. This natural combativeness has been taken advantage of and even developed through selection and rearing by the Chinese who for ages have promoted cricket fights. Crickets are reared in earthen jars and kept in small natural gourds or very expensive carved ones or in minute cells and cages. Great sums of money have been expended for especially good fighters. The average price has ranged from \$50.00 to \$100.00 apiece. It is stated that a famous fighting cricket named "Ghengis Khan" of Canton won fights with as much as \$90,000 at stake. The fighting crickets were of the ordinary field-cricket type.

Among those employed in China for singing are: the besprinkled cricket, *Gryllus conspersus* Schaum, the mitred cricket, *G. mitratus* Burmeister, and the broad-faced cricket, *Loxoblemmus taicoun* Saussure, known as the watchman's rattle. The mitred cricket has a call like the click of the weaver's shuttle and is therefore called *tsu-chi*, which means "one who stimulates spinning" (Laufer, 1927).

The tree crickets are among the finest insect musicians. Everywhere their song is heard on warm summer evenings and on overcast days. The intervals between notes are dependent upon temperature, and specialists may accurately determine the degrees of temperature by counting the rapidity of the stridulations. In China and Japan these insects are favored as household songsters. The most famous of these is the black tree cricket, *Homæogryllus japonicus* Haän, described as appearing like a large black watermelon seed, 19 mm. long. It occurs in China, Japan, India, and Java. In China it is called *kin chung* or golden bell because the notes of the males are like those of the tiny bells. In Japan also it is called the bell insect, and its notes are likened to those of the

small bells worn by the Shinto priestesses in their sacred dances. It is the only cricket which must be caged with the female to sing. The yellowish tree cricket, *kwo-lou*, *Æcanthus rufescens* Serville, is popular in Peking and Shanghai. It

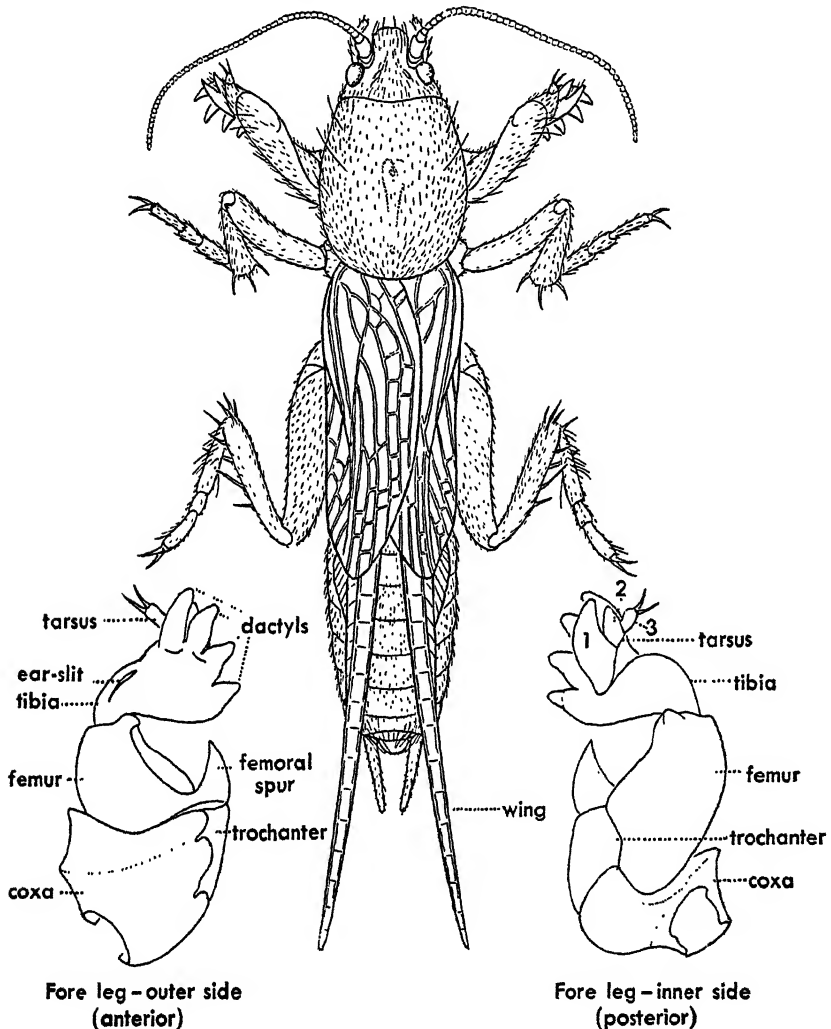


FIG. 40. The North American mole cricket, *Gryllotalpa hexadactyla* Perty, and greatly enlarged fore legs.

also occurs in the East Indies. *Æcanthus sinensis* Walker is common in China. In India *Æcanthus indicus* Saussure, a pale white or greenish species, is common while in central and western Asia and in Europe *O. pellucens* (Scopoli) is the

most abundant. In the Americas the snowy tree cricket, *O. niveus* (De Geer), a very pale green or yellowish species, the Argentina tree cricket, *O. argentinus* Saussure, a pale species, and the black-horned tree cricket, *O. nigricornis* Walker, a dark species, are by far the best known species although a number of others also occur in different localities.

Family GRYLLOTALPIDÆ Brunner 1882 (Gryl'lo-talp'i-dæ, from the Latin *gryllus*, a cricket, + *talpa*, a mole). Mole Crickets.

These insects are among the most astonishing members of the order. As the common name implies, they resemble miniature moles because of their large digging fore tibiae and their burrowing habits. It is remarkable that such large, robust, and sluggish-looking nonsaltatorial creatures, which tunnel

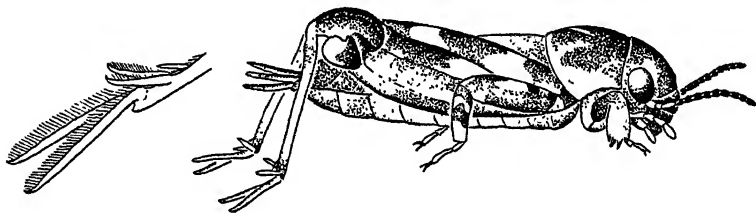


FIG. 41. The pigmy mole cricket, *Ellipes minuta* Scudder.

deep into the soil, are also able to fly with alacrity, nearly all species being winged. The colors are usually brown or black, and the bodies are covered with short, fine hairs. Auditory and stridulating organs are usually absent although the latter may be present. The tarsi are two- to three-segmented, the ovipositor is not protruded, and the unjointed cerci are long or short. The tegmina are short, and the true wings protrude behind like tails. Although there are only six genera and 43 species, mole crickets occur throughout the entire tropical and temperate world. The common mole cricket, *Gryllotalpa gryllotalpa* (Linnæus) (*G. vulgaris* Latreille), which is about 2 in. long, is the only European species. It has also been introduced into North America. The African mole cricket, *G. africana* Beauvois, is the most widely distributed member and occurs in Africa, Asia, Japan, Philippines, Australia, New Zealand, and Hawaii. It is a powerful burrower, digging three or four feet into the soil, and a strong flier. *G. coarctata* Walker is the common species in Australia; *G. ornata* Walker in India; *G. unispina* Saussure in Turkestan; *G. siamensis* Giebel in Straits Settlements, Siam, and China; *G. hexadactyla* Perty (*G. borealis* Burmeister) throughout most of North America, Central America, and South America; and *G. cultiger* Uhler in the southwestern parts of the United States. These insects are often responsible for considerable injury to cultivated crops.

An interesting group belonging to the genus *Cylindracheta*, including *C. kochi* Saussure, in Australia and Patagonia, are slender, elongated, apterous forms appearing somewhat like embiids which burrow into the stems of plants. Their tarsi are two-segmented.

Family TRIDACTYLIDÆ Brunner 1882 (Tri'dac-tyl'i-dæ, from the Greek τρεῖς, τρία, three, + δάκτυλος, a digit, toe). Pigmy Mole Crickets.

These are peculiar minute crickets, scarcely more than 10 mm. long, with the fore tibiae fossorial and the hind femora enormously enlarged for jumping. The fore and middle tarsi are two-segmented, and the hind tarsi are one-segmented or absent. The hind tibiae terminate in movable elongated plates called natatory lamellæ which spread out and probably aid in jumping from the surface of loose sand and water. The antennæ are short and 11-segmented; there are three minute ocelli; short tegmina; long wings often extending beyond the tip of the abdomen; no auditory or stridulating organs; a pair of styli; and a pair of cerci. These insects inhabit damp areas near water. They burrow freely into the sand and jump with remarkable energy. Like the grouse locusts, they seem to be equally adept on water and on land. The family is world-wide, although represented by but three genera and 55 species. *Tridactylus variegatus* (Latreille) is the common species in southern Europe, northern Africa, western Asia, and the East Indies. *T. japonicus* Haan is a Japanese species; *T. capensis* Saussure, South African; *T. tartarus* Saussure, south Siberian; *T. apicalis* Say and *Ellipes minuta* Scudder, North and Central American.

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CHAPTER IX

6. Order GRYLLOBLATTODEA¹ Brues and Melander 1932

(Gryl'lo-blat-tod'e-a, from the Latin *gryllus*, a cricket,
+ *blatta*, a cockroach.)

Grylloblattids.

Small thysanuriform apterous insects with biting mouth parts; simple metamorphosis; filiform, many-segmented antennæ; small compound eyes; no ocelli; five-segmented tarsi, those on some adult males with lobes beneath each segment; cerci long, eight- or nine-segmented; males with styli; ovipositor exserted, sword-shaped.

A very small order of curious pale, wingless insects somewhat resembling overgrown campodeids, occurring under stones, logs, or debris, or in the soil, in high mountains at elevations of 4,000 ft. or over and often near meltings now, streams, or lakes. The known species vary from 13–30 mm. in length, and their chief characteristics are best shown in the accompanying illustrations.

External anatomy.—The head is smooth with few setæ on the surface and many more on the palpi and antennæ. The compound eyes are nearly circular and small, the antennæ are composed of 28 to 40 segments which increase in length towards the tips, the mouth parts are shown in fig. 42. The mandibles have two apical and one proximal teeth. There are 10 abdominal segments visible from above. Styli are present on the ninth segment of the male. The ovipositor is exserted and sword-shaped.

These insects are not at all plentiful even in the few localities where they have been collected. Since they occur on the mountains at elevations of from 4,000 to 7,000 ft. and are hidden under moss, debris, and stones or in the soil and seem to be extremely localized in distribution, they do not appear in many collections. Because of the difficulty of securing specimens, little has been done on the biology and internal anatomy, although a number of students have studied the external structure and phylogeny.

The order is a very small one, there being a single family GRYLLOBLATTIDÆ and, according to Silvestri (1931), only one genus *Grylloblatta* Walker, although two other genera, *Ishiana* Silvestri and *Galloisiana* Caudell & King (*Galloisia*) have been erected. Representatives have been taken only in the mountains of western Canada, Washington, Montana, and California in North America and in Japan. There are four species and one variety known to date. *Grylloblatta campodeiformis* Walker, the first species described in 1914, was

¹ The insects of this order were first grouped as a family GRYLLOBLATTIDÆ Walker 1914 in the order ORTHOPTERA. In 1915 Crampton erected the order NOTOPTERA for them. In view of the fact that the name *NOTOPTERUS* was applied to a genus of fishes by Lacépède in 1800 and NOTOPTERIDÆ was used as a family name for a group of fishes by Gunther as early as 1868, it seems desirable to use the later designation, GRYLLOBLATTODEA, for the order.

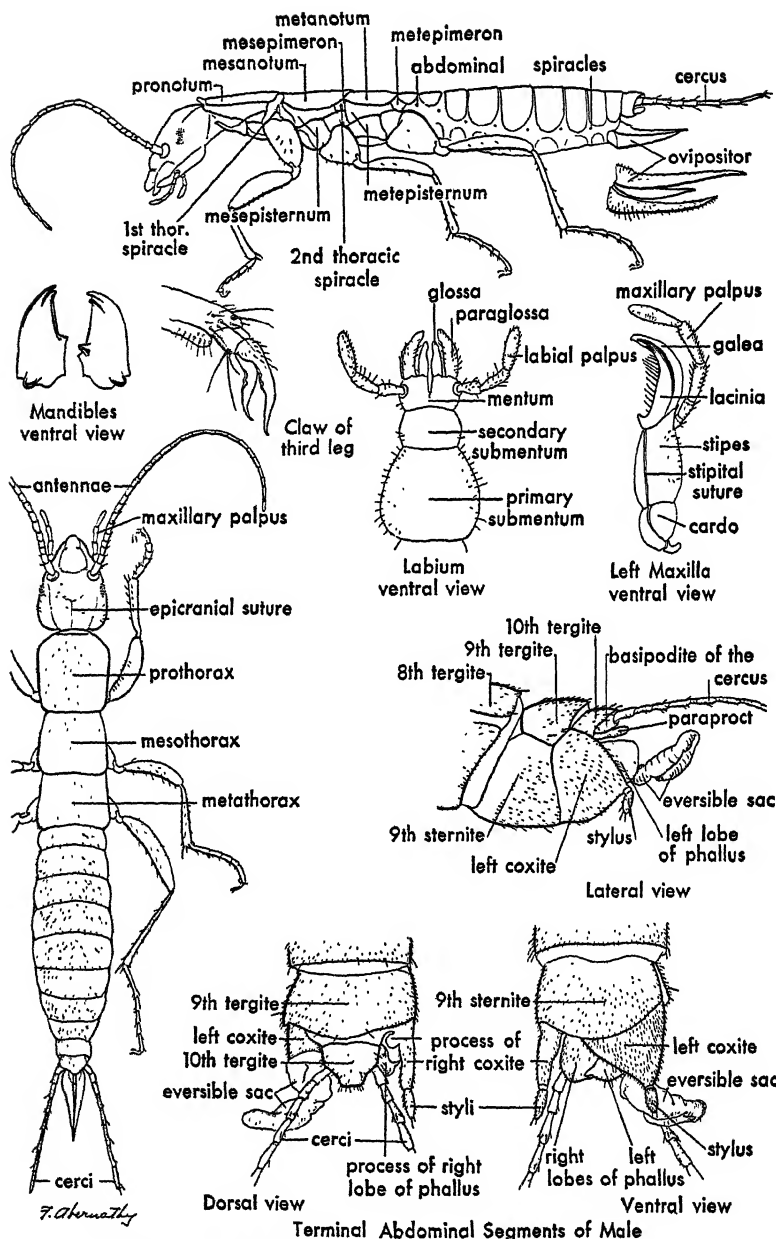


FIG. 42. *Grylloblatta campodeiformis* Walker. Adult female and genitalia of male. (Drawings from cleared and mounted specimens with certain structures from Crampton and mouth parts and male genitalia from Walker, 1919.)

collected on Sulphur Mountain, Banff, Alberta, Canada, at an altitude of 6,500 ft. The adults are amber-yellow and whitish, being covered with a fine pubescence, and measure 16–30 mm. in length. The antennæ are 28- or 29-segmented and the cerci eight-segmented. They occur in the soil or under debris, moss, or stones in moist or wet places that are covered with snow for a considerable part of the year. Specimens are therefore taken during the summer period. The insects are apparently nocturnal or negatively phototropic, rather slow of movement. In confinement they eat both plants and dead insects and only rarely attack living insects. In nature they may subsist on quantities of dead insects deposited by the melting snow and ice. Their black eggs are deposited in the soil or moss by means of the ovipositor. This species has also been taken at Lake Louise, Lake Agnes, and on Rundle Mountain in the Canadian Rockies.

A variety, *occidentalis* Silvestri, collected at 4,200 to 5,000 ft. altitudes on Mt. Baker, Wash., on June 21, 1922, by Silvestri differs from the above in having 30 to 32 segments to the antennæ. *Grylloblatta barberi* Caudell is similar to the preceding but has 40-segmented antennæ and is 20 mm. in length. It was taken on the North Fork of the Feather River, Plumas County, Calif., Jan. 23, 1923.

Grylloblatta nipponensis (Caudell and King) (*Galloisia*, *Galloisiana*), is a yellowish species 21 mm. long, with about 40-segmented antennæ and nine-segmented cerci. In the adult males there are paired membranous lobes on tarsal segments I to IV and a single lobe on segment V. The claws have a minute basal tooth. A Japanese illustration shows the abdomen to be much shorter than the head and thorax (Esaki *et al.*, 1932). The specimens were taken under and in decayed logs at elevations of 4,500 to 4,600 ft. on the slopes of the mountain Nantai San, near Chenzenji, Nikko, Japan, in August and September. The insect is described as being very active, like a cockroach.

Grylloblatta notabilis Silvestri (*Ishiana*) is straw-colored, 13.4 mm. long, and has the antennæ 37-segmented. It was taken on a mountain near Michino-o, Nagasaki, Japan, by Silvestri in June, 1925.

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CHAPTER X

7. Order BLATTARIA Burmeister 1929 ¹

(Blat-tar'i-a, from the Latin *blatta*, an insect that shuns the light, a cockroach, chafer, moth.)

Roaches, Cockroaches.

Mostly medium-sized to large apterous and winged insects with biting mouth parts; simple metamorphosis; bodies wide, depressed; pronotum large, projecting over the head; antennæ long, filiform, many-segmented; legs rather long and slender, coxæ large and free; cerci prominent, segmented; often odorous; swift runners.

Cockroaches are among the oldest and best known insects, several species having been so long and intimately associated with the human race as to be virtually domesticated in spite of the antagonistic relationships between the two. In English these insects are variously known as cockroaches, roaches, croton bugs, black-beetles, and by other names applied to particular species. In German they are called "Schaben," in French "les blattes," and in Spanish "cucarachas." Every language and almost every dialect has a name for these cosmopolitan animals. They are normally wide, flat insects with smooth, tough, and elastic integument, although some species are densely clothed with short, fine hairs. The colors are usually rather dull, being various shades of brown, gray, mahogany-red, and black, but many of the tropical forms are brilliant green, yellow, red, orange, and combinations of these and other bright colors. They are habitual runners and are remarkably swift and difficult to capture. Many species have no wings at all, others are brachypterous, and about half of the species are fully winged. In some species the females are brachypterous while the males are fully winged. All but a few species are odorous and are therefore particularly offensive. They are mostly nocturnal, but nearly all of them may be seen venturing out during the day.

External anatomy. — The head is small with a well-defined Y-shaped epicranial suture, held vertical, usually covered by the overhanging pronotum, and rarely exposed in certain forms. The long, flexible antennæ may have as many as 100 segments. The compound eyes are large and emarginate around the bases of the antennæ. A pair of lateral ocelli are usually present in the winged forms.

¹ There is considerable confusion concerning the correct designation of this order. Many entomologists relegate the cockroaches to the family BLATTIDÆ of the order ORTHOPTERA. Of the many names suggested: BLATTARIÆ Latreille 1810, DICTUOPTERA Leach 1818, CURSORIA Westwood 1839, BLATTODEA Brunner 1882, NEOBLATTARIÆ Scudder 1895, BLATTOIDEA Handlirsch 1903, it appears to the writer that the above name is preferable to BLATTARIÆ Latreille because of the more appropriate word. Order names do not end in "æ." The above name also antedates BLATTODEA Brunner, which would otherwise be appropriate. The order is divided in various ways. Only three families are included in this work. Some authors elevate all of the 23 subfamilies to family rank.

Pale ocelli-like spots called fenestrae occur in most brachypterous and apterous forms. The mouth parts are typically biting. The clypeus and submentum are large, the mandibles stout, blunt, and short. In certain genera there is a basal sclerite or prostheca at the inner base of the mandible. The large prothorax is one of the most characteristic anatomical features of cockroaches, and the pronotum may cover not only the head but the entire thorax as well. The legs are all very much alike, being rather long and slender, normally spiny or hairy, with long five-segmented tarsi terminating in a pair of claws, and with or without arolia. The coxae are extremely large and may cover the sternites almost entirely. The four basal tarsal segments are often padded beneath. The parchment-like tegmina and wings are variable and may entirely or only partially cover the abdomen when folded. The tegmina are narrow and normally pigmented while the wings are much larger, transparent or pigmented, with a large or small well-defined anal area and are folded longitudinally and rarely also vertically. The abdomen is flat and 10-segmented, but not all of the segments may be visible without dissection. The seventh sternite of the female may or may not have a groove or genital pouch for discharging the oötheca, egg case, or egg capsule. Males of some species have a pair of styli. The cerci are well developed, flat, and segmented, although not very long. Odorous or repugnatorial glands occur on the dorsum of many abdominal segments and are very prominent in certain species, especially in the males.

Internal anatomy. — The internal system of cockroaches is not greatly different from that of their near relatives the mantids, phasmids, and the orthopteroid insects. There is a large crop, a small gizzard with tough walls, eight enteric cæca, numerous fine Malpighian tubules arranged in six groups, and large salivary glands with receptacles. The tracheal system is well developed and has two large thoracic and eight small abdominal spiracles. There are three thoracic and eight abdominal ganglia. Cockroaches are oviparous and ovoviparous and normally lay their eggs in a characteristic oötheca consisting of two rows of eggs in a rather tough capsule formed in the genital pouch. The eggs descend singly from alternate ovaries and are deposited into small individual pockets in the oötheca, which often protrudes from the body. It may be dropped at or before the time of hatching or may be retained in the genital pouch until the young are born alive. Oöthecæ are lacking in some species, as in the soil-burrowing species of the genus *Panesthia* and others.

These insects are omnivorous feeders and will accept almost any kind of animal or vegetable food. A few forms are apparently strictly vegetarian and may be injurious to crops. The so-called domesticated species which inhabit the abodes of savages and civilized man as well as public buildings, stables, and ships are foragers and scavengers *par excellence*. They get into everything available and leave behind a most unpleasant odor. Their flattened bodies enable them to hide in cracks, between floors, in walls, and in other secretive places. They are particularly fond of warm, damp places and are therefore specially pestiferous in the kitchens of hotels, restaurants, barracks, and dwellings. They also find most congenial surroundings in basements and in ships. At night they

come forth to scurry across the floors, walls, and ceilings with amazing speed. Under present sanitary conditions cockroaches are not so common as they once were, but they are far from being divorced from man. Native species are to be found out of doors under stones, logs, wet leaves, and debris of all kinds. Certain species live in ants' nests, others are common on vegetation, and a few, like *Rhicnoda natatrix* Shelford, of the tropical East Indies, live near water and readily dive to the bottom where they remain for some time.

As a group they are long-lived insects. Although the life history of some of the domesticated species occupies but a few months, many species require from 1 to 5 years to complete a generation. There are from five to seven ecdyses, and the nymphs greatly resemble the adults. All have the habit of cleaning the antennæ and feet with the mouth. They are mostly gregarious, and certain species of *Panesthia* live in family communities in burrows in the soil. Still others are solitary. A few are attracted to lights.

Cockroaches occur throughout the world with the exception of the polar regions, and even these are penetrated in ships. They are, however, chiefly tropical and attain their greatest development in the hot, moist jungles. There are approximately 250 genera, 2,250 species, three families, and 23 subfamilies. According to Schröder (1925) the species are distributed as follows: Neotropical 660, Ethiopian 610, Indo-Malaysian-Papuan 500, Australian 250, Palæarctic 160, and Nearctic 70.

KEY TO IMPORTANT FAMILIES

1. Hind wings, when present, with anal area large and with many folds 2
 Hind wings, when present, with anal area small and with but one or two
 folds **CORYDIIDÆ**
2. Females with valves on the seventh sternite **BLATTIDÆ** p. 112
 Females without valves on the seventh sternite **PHYLLODROMIDÆ** p. 113

Family CORYDIIDÆ Brunner 1865 (Co-ry-di'i-dæ, from the Greek κόρυς, a helmet).

Large- and small-winged, brachypterous, and apterous species forming a heterogeneous group. Some forms are large, broad, convex, beetle-like, showy roaches, while the myrmecophilous species are very small and somber in color. The Pacific roach, *Euthyrrhapha pacifica* Coquerel, is probably the most important species of this family because of its wide tropical distribution. It is a small brown species with an orange spot on each tegmen and with rather long legs. It is both diurnal and nocturnal and runs in an erratic manner. In the semiarid southwestern part of the United States there are several interesting species belonging to the genus *Arenivaga*, the commonest of which is the erratic roach, *A. erratica* (Rehn), a small to medium-sized reddish-brown species 10–20 mm. long. The females are wingless and the males winged. They ordinarily occur under stones.

Family **BLATTIDÆ** Stephens 1829 (Blat'ti-dæ, from the Latin *blatta*, a cockroach).

The most common domesticated species belong to this family. Members may be apterous, brachypterous, or winged and vary considerably in size. Through the aid of commerce they have been distributed throughout the entire

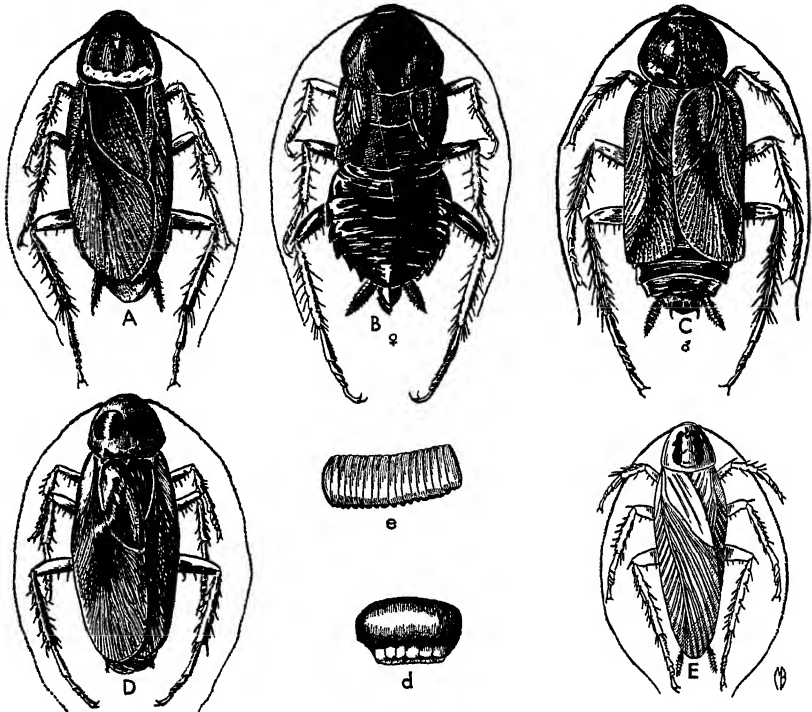


FIG. 43. Common cosmopolitan cockroaches. A, American cockroach, *Periplaneta americana* (Linn.); B, female, C, male, and d, ootheca of the oriental cockroach, *Blatta orientalis* Linn.; D, Australian cockroach, *Periplaneta australasie* (Fab.); E, adult and e, ootheca of the common cockroach, *Blattella germanica* (Linn.). (From *Insects of Western North America*.)

world and are household pests of considerable importance. The females ordinarily form a large oötheca.

The oldest known and most important member of the family is the Asiatic, oriental, or kitchen cockroach or black-beetle, *Blatta orientalis* Linnæus (Fig. 43), which is the most familiar domesticated species of the tropics and frequently occurs in the temperate regions as well. It is of medium size, very dark brown or black, and about 25 mm. long. The wings of the female are rudimentary, and those of the male, when folded, do not quite cover the tip of the abdomen. The elongated black oötheca (Fig. 43d) contains 16 eggs. This cosmopolitan species is often abundant in the huts of savages and in ships,

dwelling houses, hotels, slaughter houses, garbage dumps, and similar locations affording food and protection.

The **Australian cockroach**, *Periplaneta australasiz* (Fabricius) (Fig. 43), is a pale reddish-brown species 20–25 mm. long with a conspicuous humeral stripe at the base of each tegmen and a yellow area around the margin of the pronotum which forms a double dark blotch on the dorsum. Although called the Australian roach, it is not a native of that continent but is probably indigenous to Malaysia. It has, however, become cosmopolitan and is one of the commonest species on ships. In habits it is similar to the preceding species.

The **American cockroach**, *Periplaneta americana* (Linnæus) (Fig. 43), is the largest of these three species, attaining a length of 25–35 mm. and appearing much larger. It is indigenous to Mexico and Central America, whence it has been carried by commerce throughout the world. Its habits are similar to those of the two preceding species. It often flies, and is common in the streets and open fields by night and may also be seen during the day.

The **brown roach**, *Periplaneta brunnea* Burmeister, and *Stylophaga rhombifolia* (Stoll) are also cosmopolitan members of the family.

Family PHYLLODROMIIDÆ Brunner 1865 (Phyl'lo-drom-i'i-dæ, from the Greek φύλλον, a leaf, + δρομομεύς, that runs).

A large and varied group which may no doubt be separated into a number of valid families and many subfamilies. The species are indeed irregular in size, color, and the condition of the wings. They are widely distributed, and many are cosmopolitan.

The most important species is the **common cockroach**, **German roach**, or **croton bug**, *Blattella germanica* (Linnæus) (*Blatta*, *Phyllodromia*) which is also the most widely distributed, best known, and perhaps the most pestiferous member of the whole order, at least in the temperate regions. Its native home is believed to be Europe, but the insect has most effectively followed the human race throughout the world. It is the smallest of the common domesticated species, being only 10–12 mm. in length. The color is pale yellowish-brown with two darker brown longitudinal stripes on the pronotum. The oöthecæ are amber-yellow, with parallel edges and flattened sides, 7–8 mm. long and 3–4 mm. wide, and contain from 36 to 40 eggs arranged in parallel rows. This species is a great nuisance in kitchens, pantries, bakeries, warehouses, manufacturing plants, and ships, where foodstuffs are prepared or stored and where temperatures and humidity make living conditions congenial for the species. It is also abundant in garbage dumps and debris of all kinds. It emits a distinctive odor which may be described as pleasant until its source is known. It increases rapidly, often swarms in great numbers, and is a remarkably swift runner.

The **Surinam, burrowing, or dusty-tail roach**, *Leucophaea surinamensis* (Linnæus) (*Pycnoscelus*), is a robust tropical species of wide distribution, being 14–20 mm. long and dark brown or blackish with pale-brown wings. The apterous young are polished with the exception of the apical portion of the

abdomen which is velvety opaque, hence the common name dusty-tail. It burrows beneath piles of leaves, trash, and similar debris and is a swift runner; gives birth to living young; and often feeds on the underground stems, roots, and tubers of plants and is an intermediate host of the nematode eyeworm of poultry in the tropics.

Other cosmopolitan species of the family are: the brown-banded cockroach, *Supella supellectilium* (Serville), *Ischnoptera rufescens* (Beauvois), *Rhyparobia maderæ* (Fabricius), and *Nauphæta cinerea* (Olivier). *Eoblatta notulata* (Stål) is a tropical species similar to the common cockroach but has numerous dark markings on the pronotum. It occurs both in the household and in the open country.

The giant death's head roach, *Blaberus craniifer* Burmeister, is the largest cockroach in the United States, attaining a length of 42–55 mm. Markings on the dark brown pronotum, resembling somewhat a fanciful skull, account for the name. It occurs in Florida, West Indies, Mexico, and Central America.

The giant drummer, *Blaberus giganteus* (Linnaeus), a similar species 50 mm. long, has the remarkable habit of drumming on wood with its femora, and a large colony may make sufficient noise in a dwelling to arouse the inmates from slumber. It occurs in the West Indies, Central America, and tropical South America.

The beetle roach or cypress girdler, *Diploptera dytiscoides* (Serville), is brownish-black and as long as 45 mm. The wings are folded longitudinally and also transversely, and the tegmina are without veins. The general appearance is that of a ground or water beetle. It is both nocturnal and diurnal, ovoviviparous, and often abundant on plants which may be injured by its feeding. It occurs throughout the tropical Pacific Islands.

The brown wingless cockroach, *Cryptocerus punctulatus* Scudder, is a curious polished, dark-brown species with reddish antennæ and legs, which measures 23–30 mm. in length. It occurs in wet, rotting wood or under the bark of dead logs upon which it subsists. It occurs in many parts of the United States from New York and Georgia on the Atlantic seaboard to Washington and California on the Pacific coast.

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CHAPTER XI

8. Order PHASMIDA Leach 1815¹

(Phas'mi-da, from the Greek *φάσμα*, a specter, an apparition.)

Phasmids, Walkingsticks, Leaf Insects.

Large insects; greatly modified and stick-like or leaf-like in form; simple metamorphosis; biting mouth parts; antennæ usually long, filiform, and many-segmented, rarely short; compound eyes small; ocelli two or three or absent; apterous or winged; tegmina small, scale-like or absent; cerci small and unsegmented.

These are among the most curious and bizarre of insects, being variously called "phasmids," "walkingsticks," "stick and leaf insects" in English; "Gespenster" (phantoms), "stabheuschrecken" (stick locusts), and "wandelnde Blätter" (walking leaves) in German; and "phasmes" and "phyllies" in French. As these names indicate, the members are stick-like or leaf-like in appearance. The bodies are often greatly elongated or leaf-like, and smooth or spiny but not hairy.

External anatomy. — The head is usually small, the antennæ long and filiform or short and setiform; the prothorax is small, but the mesothorax and metathorax are greatly lengthened in the linear forms and short in the leaf forms. The legs may be long and slender and far apart, smooth or spiny, or short and ornamented with peculiar outgrowths. The tarsi are normally five-segmented (three-segmented in *Timema*), the first segment longest, last terminating in a pair of claws and an arolium. A suture between the femur and trochanter permits the easy loss of a leg, which may be generated in part with a molt. Apterous forms are most often seen in the temperate regions, but in the tropics the tegmina and wings are often developed to a remarkable degree. The tegmina are frequently reduced and may be very small or even absent when wings are well developed. In other cases the tegmina may be developed and the wings vestigial in the female. The front costal portion of the wings is often thickened and pigmented like the tegmina while the membranous areas are transparent or brilliantly colored. The tegmina and wings are folded flat on the back at rest. Stridulating and auditory organs are not evident. The first abdominal segment is often closely fused with the metathorax, the other segments being free. There are nine or 10 segments visible. In the female the eighth sternite forms a groove-like egg-laying process and three pairs of gonapophyses lie behind this plate. There are two thoracic and eight abdominal spiracles. Repug-

¹ This order is commonly listed as a family, PHASMIDÆ, in the order ORTHOPTERA. Other important names applied to the order are PHASMODEA Burmeister 1838, AMBULATORIA Westwood 1859, PHASMOIDEA Handlirsch 1903, GRESSORIA Börner 1904, and PHASMATODEA Jac. and Bianchi 1905.

natorial glands, opening on the thorax, are often present beneath the prothorax or at the bases of the wings. There is noticeable sex dimorphism in which the size, length of the antennæ, size and presence of the wings are concerned.

Internal anatomy. — The internal anatomy is much like that of the ORTHOPTERA. The alimentary canal is without convolutions; the gizzard ves-

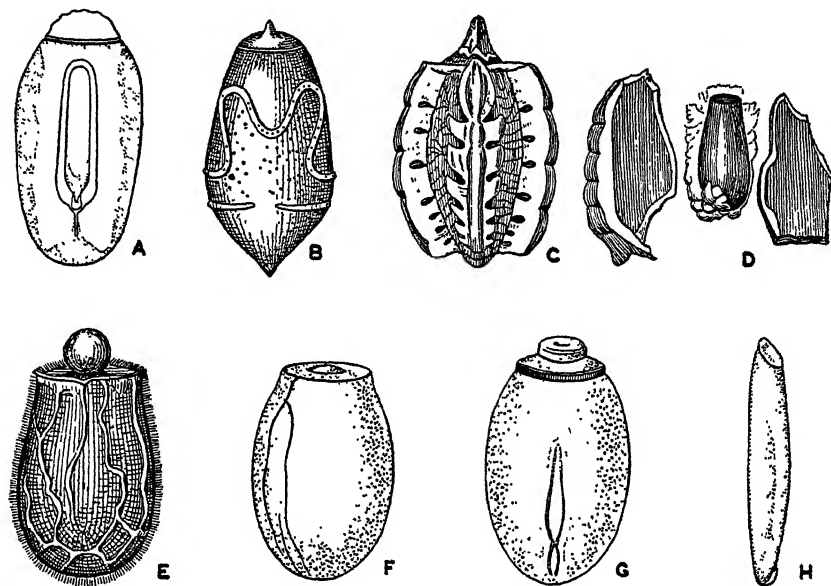


FIG. 44. Egg capsules or oöthecæ of phasmids. A, *Diapheromera femorata* (Say) (after Severin, 1910); B, *Platycrania viridana* (Olivier) (after Sharp, 1895); C, *Pulchriphyllium scylthe* (Gray) and D, same separated to show egg (after Murray, 1856); E, *Podacanthus wilkinsoni* Macleay (after Froggatt, 1907); F, *Carausius morosus* Brunner (after Leuzinger, 1926); G, *Bacillus rossia* Fab. (after von Wattenwyl, 1882); H, *Diapheromera arizonensis* Caudell from egg laid in confinement.

tigial; enteric cæca absent; anterior portion of the mid-intestine with thick vermiform muscle bands, the posterior portion drawn out and with many glandular papillæ. The numerous Malpighian tubules are arranged in bundles. The ovipositor is greatly reduced. There are three thoracic and five abdominal ganglia.

Phasmids reach their greatest development in numbers, size, and form in the tropics, where certain members attain a body length of from 9–13 in., being among the largest of insects. The leaf forms are limited to the moist tropical jungles, especially those in the East Indies and the adjacent islands. Their mimicry of leaf structures is almost perfect. In the warmer temperate regions dull-colored, wingless, stick-like forms occur but seldom in great numbers. There are 300 known genera and 2,000 described species. They are most abundant in the Indo-Malaysian-Oceanian-Papuan region and in Central and South America, with a fair representation in the Ethiopian and Australian regions. In

this country there are about seven genera and 12 species, all apterous except one Florida species.

Phasmids have dull or bright cryptic colors and may resemble to a remarkable degree twigs, leaves, spiny branches, mosses, lichens, and other forms of plant life, the mimicry being best developed in the females. They are largely arboreal and move slowly. Death feigning is one of their remarkable accomplishments. They are strictly vegetarian and in some localities are sufficiently abundant to injure forest trees. Development is slow and it may often require $1\frac{1}{2}$ years to complete the life history, there being from three to six ecdyses. Both sexes are usually present, but parthenogenesis and a corresponding scarcity of males are frequent. The eggs are deposited singly and usually fall to the ground where they may remain over the winter or for 1 or 2 years before hatching. They are exceptional in that a curiously molded and sculptured enveloping capsule or case of varying shape and thickness serves as a protection and gives them the appearance of seeds or inanimate objects, as shown in Fig. 44. In eucalyptus forests of Australia, when phasmids are abundant, the frequent dropping of the seeds sounds like rain. Living forms are sensitive to cold and perish in the cooler limits of their distribution with the approach of winter, only the eggs surviving. The eggs of the temperate forms appear generally to lack the enveloping capsule.

KEY TO SUPERFAMILIES

1. Middle and hind tibiae with sunken arolia on the underside of the apex
PHASMOIDEA
2. Middle and hind tibiae without sunken arolia on the underside of the apex. **BACTERIOIDEA** p. 122

Superfamily PHASMOIDEA Brues and Melander 1932

(Phas-moid'e-a, from the Greek *φάσμα*, a specter, an apparition.)

KEY TO FAMILIES

1. First abdominal segment fused with metanotum and as long as or longer than the latter; apterous or winged; tegmina reduced in size. . . 2
 First abdominal segment distinct from and shorter than the metanotum; apterous; bodies flattened or long and slender. **BACILLIDÆ**
2. Antennæ of male long and of female short; metanotum not longer than wide; tegmina of female large and leaf-like; sides of abdomen with flattened outgrowths. (Leaf Insects, Walking Leaves.) . . . **PHYLLIDÆ** p. 119
3. Antennæ long in both sexes; metanotum longer than wide; abdomen without lateral outgrowths **PHASMIDÆ** p. 120

Family BACILLIDÆ Brunner 1893 (Ba-cil'li-dæ, from the Latin *bacillum*, a little stick).

The members of this family are widely represented in the Malayan, Ethiopian, Palearctic, and Neotropical regions and in Madagascar. They make up a

group of some 17 genera and are varied in form and structure and armature. *Acanthoclonia erinacea* (Redtenbacher) of Colombia, *A. sævisima* (Westwood) of Brazil, *Setosa versicolor* Redtenbacher of Colombia, and other species have curious leaf-like and often somewhat spiny outgrowths on the body as well as on the legs of some species. *Bacillus gallicus* Charpentier and *B. rossia* Fab. are the common species in southern Europe and Algeria. The former ranges northwards to central Europe.

Family PHYLLIDÆ Brunner 1893 (Phyl'li-dæ, from the Greek φύλλον, a leaf).
Leaf Insects, Walking Leaves.

These are among the most remarkable insects known because of the perfection with which they are able to simulate their surroundings. Their bodies are

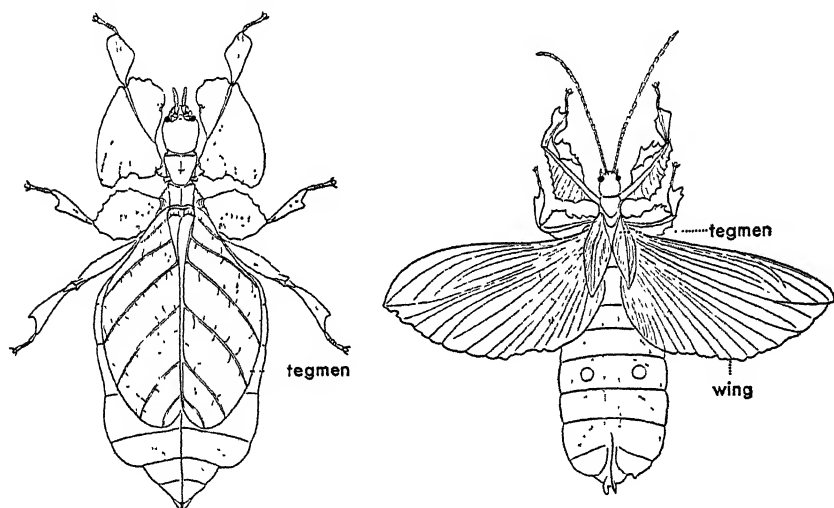


FIG. 45. Oriental leaf phasmids. A, female *Phyllium siccifolium* (Linn.); B, male *Pulchriphyllium scythe* (Gray) (B after Murray, 1856.)

broad and flat, and the tegmina and wings are often the most perfect examples of mimicry known. Not only do they simulate the colors and shapes of leaves, but they even show the veining as well, and the legs have leaf-like appendages. They are inhabitants of the moist tropical regions of the Ethiopian, Indo-Malaysian, and Polynesian regions. Specimens are comparatively rare in most insect collections and are always objects of great interest.

Among the best known species are the following:

Phyllium siccifolium (Linnæus), is one of the best examples of the leaf-like forms. The females lack ocelli, have their tegmina greatly enlarged, and are wingless, whereas the males have ocelli, only abbreviated tegmina, and well-developed wings. The specimen figured has the body 85 mm. long and 37 mm.

wide. This species has been collected on the island of Amboina of the Malay Archipelago. Other species of *Phyllium* occur in the East Indies, Ceylon, and the Philippines. *Pulchriphyllium scythe* (Gray) occurs in India, and related species abound in Ceylon and the East Indies. Members of the genus *Chitoniscus* Stål occur in the Fiji, Loyalty, and Bismarck Islands.

Family PHASMIDÆ Brunner 1893 (Phas'mi-dæ, from the Greek *φάσμα*, an apparition).

All forms have long antennæ, simple or pectinate claws, lobed or abbreviated tegmina, body and legs usually spined and toothed, and the fore femora often with leaf-like dilations. Winged and apterous forms are common. The **musk mare**, *Anisomorpha buprestoides* (Stoll), is one of the most interesting phasmids in North America. It is a large wingless light-brown insect 39–77 mm. long, with dark, longitudinal stripes. The males are only about half as large as the females. According to Blatchley, this insect has glands beneath the prothorax which, when it is disturbed, exude copiously a white fluid of a peculiar but pleasant odor which accounts for its common name. It occurs in the southern states from South Carolina to Mississippi. A related species, *A. ferruginea* (Beauvois), a reddish species 30–56 mm. long, is also southern but ranges as far north as the Great Lakes.

The timemas, of which *Timena californica* Scudder is the best known member, are wingless, queer-looking insects, green or pinkish in color and strictly arboreal in habits. The tarsi are only three-segmented. The California species is 14–22 mm. long and lives in oak, madrona, manzanita, silk tassel bush, laurel, and coniferous trees in California, Oregon, and Washington. They are collected by beating the trees over a sheet.

The Brazilian *Prisopus spiniceps* Burmeister (*P. flavelliformis* Serville) and *P. spinicollis* Burmeister are of special interest because of their reported habit of living on rocks in running water in the mountains of Brazil. The more recent discovery of a new species, *P. fisheri* Gahan (1912), together with observations on the habits and a study of their adaptive structures and cryptic colors, has led to convincing claims that these phasmids are frequenters of trees and faithfully mimic the texture and colors of the bark on which they rest.

Some of the Australian and New Zealand members of this family are remarkable. *Podacanthus wilkinsoni* Macleay is a green and brown species with green and rose-pink wings that attains a length of 90 mm. and a wing spread of 125 mm. It is gregarious in the eucalyptus forests of Australia where it defoliates the trees and is known as Lourie's ringbarker. It also occasionally damages fruit trees. The spiny leaf phasmid, *Extatosoma tiaratum* Macleay, is a stout, spiny species which attains a length of 127 mm. The males have ample wings while the females have only short wing stubs. It also occurs in the orchards of Australia. The great spiny, apterous *Argosarchus horridus* White of New Zealand is dull brown with lichen-like patches. It is one of the largest phasmids and varies from 127 to 152 mm. in length.

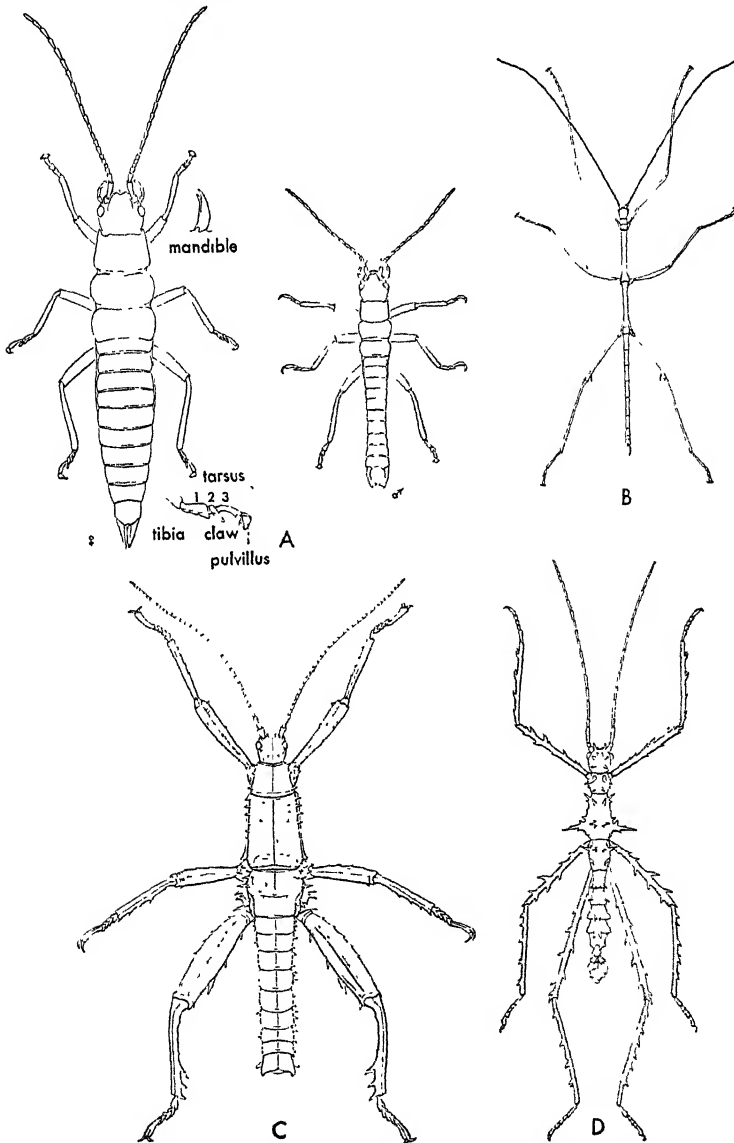


FIG. 46. Various types of walkingsticks. A, *Timema californica* Scudder, female and male; B, *Diapheromera arizonensis* Caudell, male; C, the giant *Eurycantha horrida* Boisduval of New Guinea, eight to 10 inches long; D, *Acanthoclonia carrikeri* Hebard of Colombia. (D, after Hebard, 1919.)

Superfamily BACTERIOIDEA Brues and Melander 1932

(Bac'ter-i-oid'e-a, from the Greek *βακτήρια*, a staff.)

KEY TO FAMILIES

1. First abdominal segment shorter than wide or but little longer than wide and very much shorter than the metanotum; apterous; very slender BACUNCULIDÆ
2. First abdominal segment as long as or longer than the metanotum; winged or apterous BACTERIIDÆ

Family BACUNCULIDÆ Brunner 1893 (Bac'un-cu'li-dæ, from the Latin *baculum*, a rod, stick, + *unculus*, a little hook or barb).

The members of this family are all apterous, long and slender, stick-like species in which both the front legs and the antennæ are quite long. In this country there are four genera and somewhat over a dozen species. The best known and most widely distributed species is *Diapheromera femorata* (Say), a large species which is gray, brown, green, or a combination of these colors, and 68-100 mm. long. It appears to prefer oak, wild cherry, locust, and hickory, but also feeds on other trees. The adult stage is attained about the middle of August. The small seed-like eggs are without protective cases and are dropped among the dead leaves on the ground where they lie dormant during the winter and hatch in the spring. All of the adults die with the coming of winter. This species occurs east of the Rocky Mountains throughout the United States and southern Canada. *D. veliei* Walsh occurs in the prairie states extending from Minnesota to Texas. *D. carolina* Scudder is limited to the southern states. *D. arizonensis* Caudell occurs in Arizona, southern California, and northern Mexico. *Parabacillus coloradus* (Scudder) is found along the east and west sides of the Rocky Mountains in Colorado and Nebraska. The giant walkingstick, *Megophasma dentricus* (Stål), which measures up to 150 mm. in length, occurs in the southern states and has been taken as far north as Missouri and Iowa.

Family BACTERIIDÆ Brunner 1893 (Bac'ter-i'i-dæ, from the Greek *βακτήρια*, a small staff).

A family of winged and apterous, mostly stick-like forms confined chiefly to the tropics of the Indo-Malaysian, Oceanian, Neotropical, and Australian regions with a few Ethiopian. The giant brown phasmid, *Palophus titan* Sjöstedt, of Australia is truly a titan among insects, measuring 10 in. in length and in wing expanse. The body is grayish-brown, blotched with blue-black, and the wings are pale brown with red bases. It is called the walking straw or animated stick. *Eurycantha*¹ *horrida* Boisduval is an immense wingless, spiny species brown in color and measuring 8-10 in. in length. It occurs in New

¹ In a recent paper Günther (1933) places this genus in the subfamily PHIBALOSOMINÆ and the family PHASMIDÆ.

Guinea and Woodlark Island. A similar but much smaller species, *E. australis* (Montrousier), is less spiny, has greatly enlarged and keeled hind femora, and lives on Lord Howe Island, in a locality where other species of the genus occur.

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CHAPTER XII

9. Order MANTODEA Burmeister 1838¹

(Man-to'de-a, from Greek *μάντις*, a prophet, + *εἶδος*, form, shape, kind, like.)

Mantids, Preying Mantids, Praying Mantids, Soothsayers.

Medium-sized to large insects with greatly elongated prothorax; forelegs modified for capturing and holding prey; biting mouth parts; simple metamorphosis; head small, triangular, freely movable on a slender neck; compound eyes large; ocelli usually three or none; apterous, brachypterous, or winged; wings folded flat and overlapping sides of body; middle and hind legs long and slender, tarsi five-segmented; cerci short and segmented.

Because of their peculiar attitude in seeking living prey, in which the forelegs are held in front of the face as if in prayer or supplication, many strange ideas have been associated with these insects. The early Greeks called them "prophets" or "diviners," and the Arabs thought they prayed constantly with their faces turned towards Mecca. They were also referred to as "nuns," "saints," "mendicants," "preachers," and to the less superstitious, as "mule killers," "rear horses," "devil horses," and "preying flowers." The Germans call them "Fangheuschrecken" (praying crickets) and "Gottesanbeterinnen" (worshippers of God), the French refer to them as "les mantides," the early settlers of Australia called them "the Hottentot's god" because of their prominence in Bushman mythology, and in Australia they were also known as "forest ladies."

External anatomy. — The general form is rather long and slender or somewhat cylindrical, although some are flattened and leaf-like, resembling certain phasmids. The color is cryptic and protecting, being usually green, but may be brown, or gray, or even metallic. The body is smooth and normally without hair, although sometimes spiny or with leaf-like appendages. The head is rather small, triangular, with vertical face, and freely movable on a slender neck. The antennæ are long and filiform, or bipectinate in the males of *Empusa* Illiger, and with as many as 100 segments. The compound eyes are large and somewhat reniform to accommodate the antennæ. The ocelli are arranged in a triangle, being three in number or absent. The prothorax is always greatly lengthened and may have smooth or toothed margins and rarely leaf-like extensions. The mesothorax and metathorax are short and wide. The front legs are singularly modified to seize and hold living prey. The coxæ are very long; the femora large

¹ Mantids have generally been placed in the family MANTIDÆ of the order ORTHOPTERA. They have also been designated as DERATOPTERA Clairville 1798, ELYTHROPTERA Latreille 1806, DICTUOPTERA Leach 1817, DACNOSTOMATA Westwood 1839, PHYLLOPTERA Packard 1883, EXOPTERYGOPTERA Sharp 1899, MANTOIDEA Handlirsch 1903, PANDICTYOPTERA Crampton 1917, PANISOPTERA Crampton 1919.

with a median groove bordered on either side by a row of sharp, strong spines of varying sizes; the tibiae are also spined and sufficiently narrow to fit into the

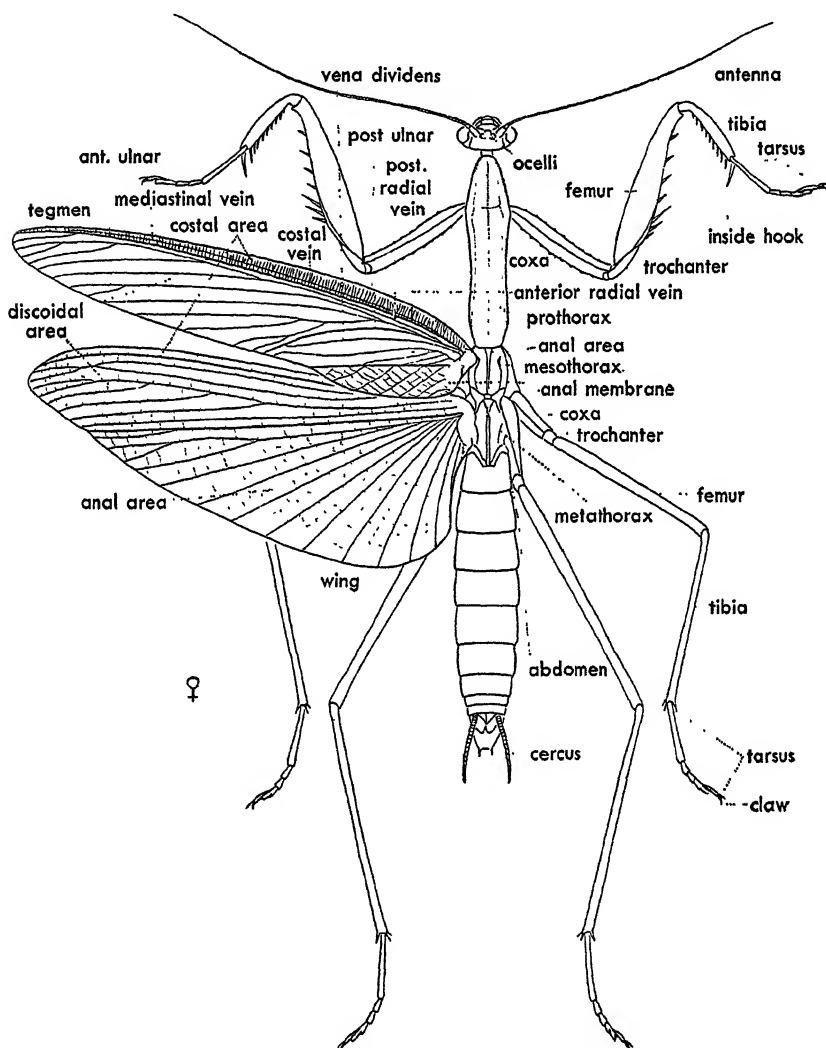


FIG. 47. The Chinese mantid, *Paratenodera sinensis* (Saussure), with left wings spread and right wings removed to show important anatomical characters.

grooved femora like a knife blade. The armature and carriage of these raptorial legs are shown in the accompanying illustrations. The middle and hind legs are slender or rarely expanded and for locomotion only. The slender tarsi are five-segmented, terminated by a pair of claws without an arolium. Small paired

outgrowths are often present on the undersides of segments II and IV. The wings may be well developed, short, or absent. When folded flat over the dorsum they may extend over and around the sides of the body. The tegmina are usually narrow, partly or wholly pigmented, heavily veined, and frequently reduced or aborted, especially in the female. In many only that portion is pig-

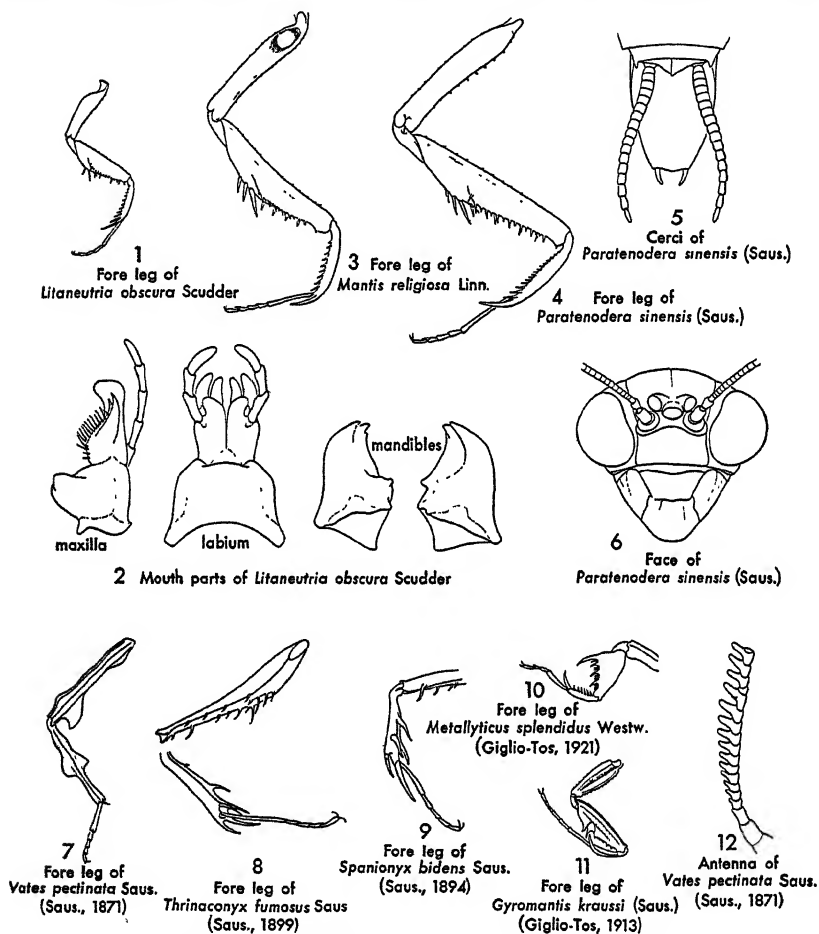


FIG. 48. MANTODEA. Mouth parts and appendages.

mented which overlaps the sides. The wings are often large, with complicated venation, transparent or pigmented and sometimes brightly colored, and are folded longitudinally. The abdomen is 10-segmented, but all segments are not apparent, there being nine dorsal segments visible in both sexes, six ventral segments visible in the female and eight in the male. The seventh sternite of the

female is turned up. The 10th tergite forms the supra-anal plate. The ninth segment of the male usually bears a pair of styli. Rather short, flattened, and segmented cerci are present. The ovipositor is not exerted. Auditory and stridulating organs are not common although some species are recorded as stridulating.

Internal anatomy. — The internal structure is not greatly different from the ORTHOPTERA and PHASMIDA. The alimentary canal is straight or winding, the crop spacious, the gizzard rudimentary, the salivary glands large and

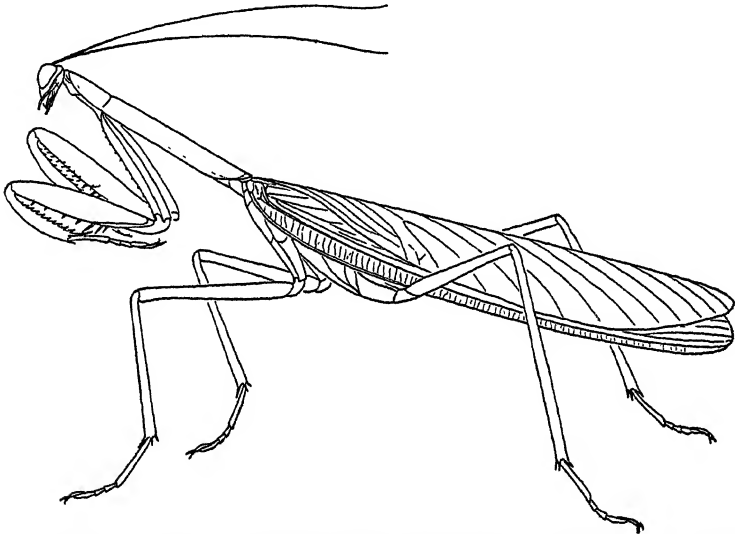


FIG. 49. The Chinese mantid, *Paratenodera sinensis* (Saussure), showing natural hunting pose.

with receptacles, and with eight tubular enteric cæca and about 100 Malpighian tubules. There are three thoracic and seven abdominal ganglia and two thoracic and eight abdominal spiracles.

Mantids are largely arboreal although certain wingless species are ground inhabitants. They appear to be wholly carnivorous and devour only living prey, which they capture by watchful waiting or by cautious stalking and which they eat leisurely while the victim writhes. The diet consists of large and small flies, leafhoppers, grasshoppers, caterpillars, and, in fact, any insect that can be overpowered, as well as very small frogs, lizards, and other animals. Although slow in walking, they are remarkably energetic with their forelegs and strike swiftly. They are pugnacious, and, while accused of cowardice, caged specimens have repeatedly captured wasps and bumblebees which stung them several times and were as often forcefully dropped, only to be seized again until subdued. The males are combative and fight to the death. In China they are caged for such encounters. The females are no less vicious and often devour the males. However, in spite of their cruel ways, they are considered beneficial

to man because of their destruction of plant-destroying insects. The eggs are deposited in two or more rows in a capsule or oötheca formed of a viscid or frothy quick-drying material exuded by the female for that purpose. From 20 to 40 eggs may be enclosed in a single oötheca, and four or five such capsules may be produced by each female. The oöthecæ are constructed so as to be more or less characteristic for each species or genus and are attached to plants, rocks, or other convenient places. In the cooler limits of distribution only the eggs survive the winters. The eggs, although apparently so well protected, are heavily parasitized by minute parasitic HYMENOPTERA. Some species are parthenogenetic. In certain species the young, upon hatching, are suspended by a silken

thread exuded from a pair of papillæ on the last sternite.

The life histories have been little studied. There are from three to 12 ecdyses, and the complete life cycle requires 1 year or more.

The order MANTODEA comprises some 400 genera, about 1,550 species, and 17 subfamilies, many of which are given family rank. They are chiefly tropical in distribution. By far the greatest numbers occur in the Ethiopian region, with lesser representations in the Neotropical, Oriental, Palæarctic, and Australian regions in the order listed.

Family MANTIDÆ Saussure
1869. Mantids.

The commonest North American species is the **Carolina mantid**, *Stagmomantis carolina* (Linn.), which ranges from Cuba, Mexico, and the Gulf states north to New

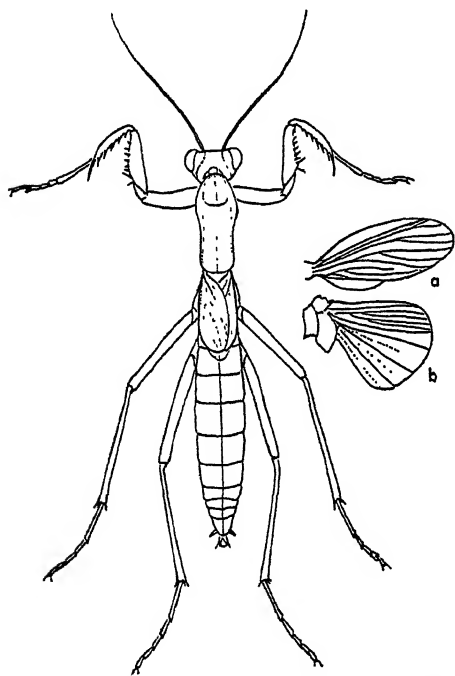


FIG 50. A brachypterous mantid, *Litaneutria obscura* Scudder. a, tegmen; b, wing.

Jersey and even New York, and west to southern Indiana, Utah, and Arizona. It is grayish-brown with darker mottlings and 48–57 mm. long. The oöthecæ are large, elongated egg masses, consisting of from 20 to 40 eggs laid in parallel rows, are brown with whitish dorsal stripe, and about 25 mm. long. They are most frequently found on the bare branches of deciduous trees and shrubs during the winter months. They may be incubated and the young reared in confinement.

Probably the best known species is the **European mantid**, *Mantis religiosa* Linnæus, which occurs throughout southern Europe, northern Africa, and

middle Asia, being common in India, China, and Japan. It was introduced into the United States on nursery stock from Europe and was first noted near Rochester, N. Y., in 1899. Since then it has spread throughout much of the eastern area. It is a pale-green species varying from 47–56 mm. in length. The Chinese mantid, *Paratenodera sinensis* (Saussure), indigenous to China and

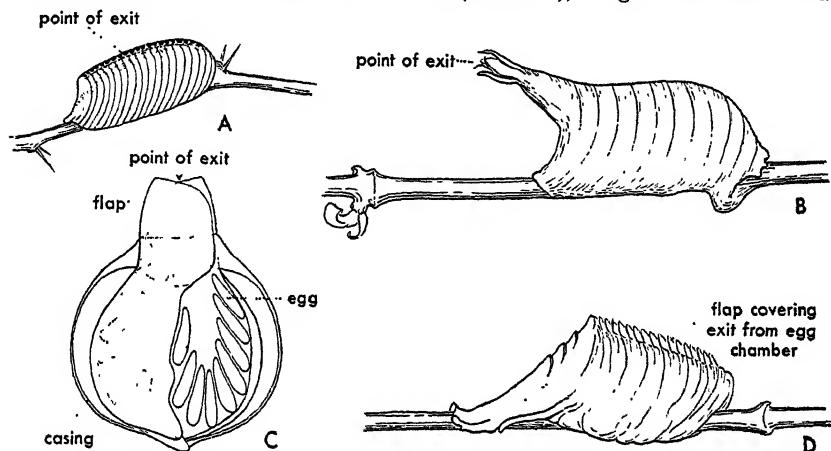


FIG. 51. Oothecae or egg capsules of mantids. A, generalized type; B, *Oligonyx mexicanus* Saussure and Zehntner; C, sectional and D, exterior aspects of *Paratenodera sinensis* (Saussure). (C and D after Kershaw, 1910.)

Japan, has also become established in the eastern states, having been first taken near Philadelphia, Pa., about 1896. Members of this species are usually an elegant bright- or yellowish-green, though some of the males are entirely brown, or green with brown markings on the tegmina and wings. It is much larger than the preceding species and measures from 83–104 mm. in length. It has been purposely established in a number of states and also occurs in Hawaii.

In the southwestern states and in northern Mexico the small brachypterous species belonging to the genus *Litaneutria* Saussure are most often seen. They are usually grayish-brown and scarcely more than 25 mm. in length and occur in the dry grass and on bare paths and roads. Of these the obscure mantid, *L. obscura* Scudder (Fig. 50), is the commonest.

The bark-haunting mantids of Australia are an interesting group in the subfamily PERLAMANTINÆ. They are small, winged or apterous species mimicking in color the bark of the particular trees which they frequent. Some of the apterous females resemble large ants in appearance.

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CHAPTER XIII

10. Order DERMAPTERA Leach 1815 ¹

(Der-map'te-ra, from the Greek *δέρμα*, skin, + *πτερά*, wings; referring to the texture of the tegmina and bases of the wings.)

German, Ohrwürmer. French, Forficules, Perce-oreilles.

Earwigs, Arixenids.

Small to medium-sized, elongate, smooth, tough, chitinous insects with biting mouth parts; simple metamorphosis; with or without short truncate tegmina which conceal all but the tips of the much-folded wings; body terminating in a pair of weak or strong, hairy, burnished, smooth pincers or forceps.

ANATOMICAL CHARACTERS

<i>External</i>	<i>Internal</i>
Size — medium.	Digestive System.
Shape — elongate, compressed dorsally.	<i>Alimentary Canal</i> — <i>oesophagus</i> — long;
Exoskeleton — normally smooth, shining,	<i>crop</i> — almost globular; <i>gizzard</i> —
Sometimes pubescent.	tubular; <i>mid-intestine</i> — straight or
Head — prognathous, small, rounded or	with one or two coils, without <i>enteric</i>
broad, with Y-shaped epicranial suture.	<i>cæca</i> ; <i>Malpighian tubules</i> — eight to
Eyes — compound eyes and ocelli well	20, usually arranged in two groups;
developed, vestigial, or wanting; ocelli	<i>hind intestine</i> — with partial or com-
usually vestigial or absent.	plete spiral and with six <i>rectal papillæ</i>
<i>Mouth parts</i> — similar to those of the	(see also ORTHOPTERA).
ORTHOPTERA. Labium, ligula, and	Circulatory System. Similar to ORTHOP-
superlinguæ bilobed; maxillary palpi	TERA. A dorsal chambered vessel
five-segmented; labial palpi three-	serves to force the blood forward to the
segmented.	head.
Thorax — well developed; pronotum large;	Respiratory System.
mesonotum fused with first abdominal	Elaborate tracheal system.
segment.	<i>Spiracles</i> — 10 pairs: two thoracic and
<i>Tegmina and wings</i> — absent, vestigial,	eight abdominal.
or functional.	Nervous System.
<i>Tegmina</i> — shorter than abdomen, trun-	Cephalic ganglia — two.
cate, leathery, veinless.	Thoracic ganglia — three.
<i>Wings</i> — semicircular, folded fan-like	Abdominal ganglia — six.
longitudinally and twice transversely;	
numerous weak veins.	

¹ The term DERMAPTERA was first employed by Carl DeGeer in 1773 for the true bugs. W. E. Leach and Wm. Kirby in 1815 were the first to apply it to the earwigs. A. M. C. Dûméril coined the name LABIDOURES (LABIDURA) for them in 1806, and J. O. Westwood erected the order EUPLEXOPTERA for them in 1839. For many years they were considered as a family, FORFICULIDÆ, of the ORTHOPTERA.

ANATOMICAL CHARACTERS—*Continued*

<i>External</i>	<i>Internal</i>
<p>Thorax—<i>continued</i> <i>Legs</i> — short and stout; coxæ widely separated; tarsi three-segmented, each with a pair of claws and with or without empodium or arolium. Abdomen — 11-segmented (see text); odorous glands on basal tergites of many species. <i>Forceps</i> — modified cerci; segmented in young of some species; normally unsegmented and simple or pincer-like; variable in size and form, largest in male. <i>Genitalia</i> — see text. <i>Spiracles</i> — two pairs on thorax and eight pairs on abdomen.</p>	<p>Reproductive System. <i>Female</i> — variable. Ovarioles in three rows the length of oviduct, in a single series, or five, eight, or 10-12; very short or elongate. <i>Male</i> — variable. Testes composed of a pair of elongated follicles, a pair of filiform coiled follicles, or a pair of globular bodies, each with 16 short follicles. <i>Vas deferens</i> — slender. Ejaculatory duct with one or two openings.</p>

Some of the early ideas concerning the earwigs are: that they occasionally enter the ears of sleeping human beings and even penetrate the brain; that the forceps resemble to a remarkable degree the pincers used to puncture human ears for the insertion of earrings; that the expanded wings of the earwigs resemble somewhat the shape of the human ear. In view of the nocturnal crawling habits of these creatures, which are always seeking small passages for concealment, it seems likely that they might enter the human ear, especially where they are abundant and the natives not too particular about their habitations.

They are among the more ancient of insects, and fossil remains have been found in the Lower Lias, the oldest division of the European Jurassic, at Aargau, Switzerland; the Jurassic of eastern Siberia; the Tertiary, Oligocene, and Miocene in general; and the Lower Miocene of Florissant, Colo. In the Tertiary, where they are found most frequently, the greatest numbers belong to the single genus *Labiduromma* Scudder, and differ little from present living forms.

As a natural group these insects are quite homogenous and are without striking variations in either structure or habits.¹ The color is for the most part various shades of black and brown, although certain tropical species are brilliant.

Earwigs are nocturnal, terrestrial animals which seek refuge in moist, shady places under stones, boards, bark of trees, and in piles of refuse or manure, as well as in hollow stems of plants, cracks in the soil, and, in fact, anywhere secluded from the light. They are generally omnivorous feeders. In the cooler regions they appear to be mainly herbivorous, living for the most part on dead or decaying vegetable matter but frequently eating all or parts of living plants. But in the tropics they are often carnivorous, and cannibalistic to a consider-

¹ The ARIXENINA are quite different from the true earwigs and might appropriately be placed in a separate order.

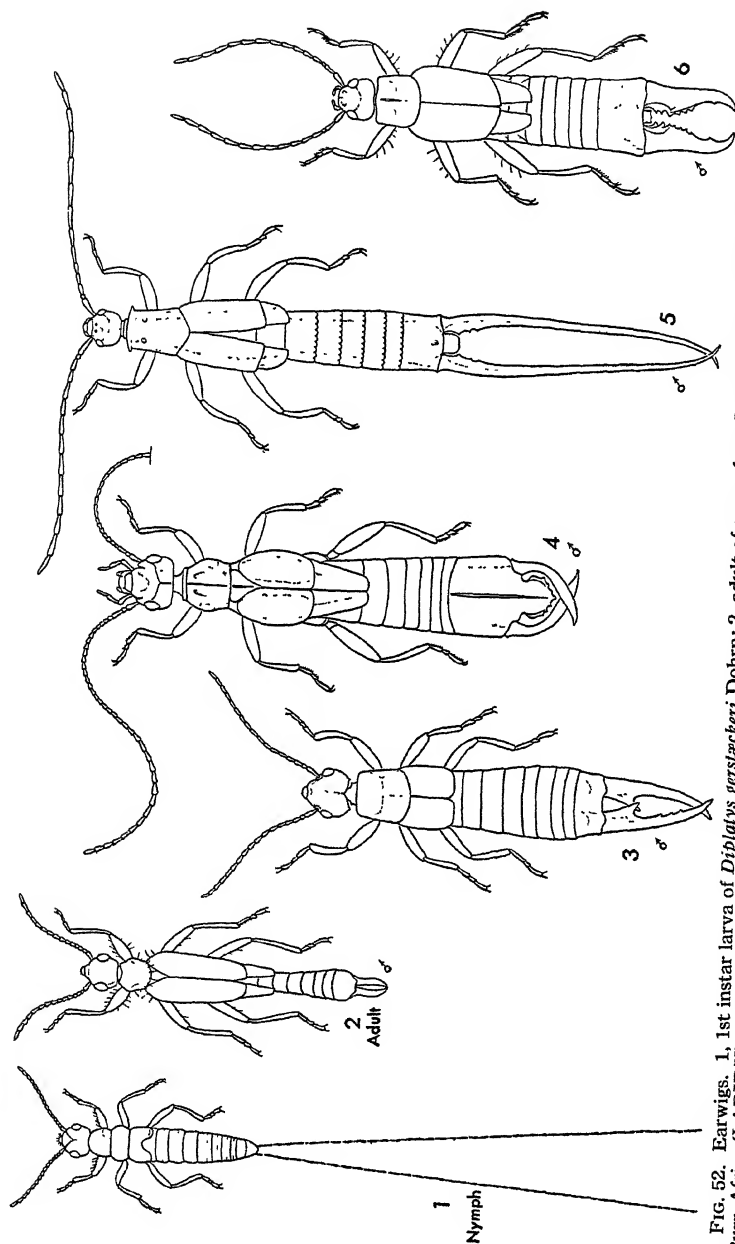


FIG. 52. Earwigs. 1, 1st instar larva of *Diplatys gerslackeri* Dohrn; 2, adult of same, from India (PYGIDICRANIDÆ); 3, *Naia figinii* Burr, Africa (LABIDURIDÆ); 4, *Apachyus feæ* Bormans, southern Asia (APACHYIDÆ); 5, *Auchenomus longiroceps* Karsch, Madagascar (LABIDÆ); 6, *Adiatetus tenebrator* Kirby, southern India (CHELISOCHIDÆ). (1 after Westwood, 1881; 2-6 after Burr, 1913.)

able degree. They devour many kinds of insect larvæ, notably maggots, as well as their freshly molted kin and their own dead. They are largely unisexual, the

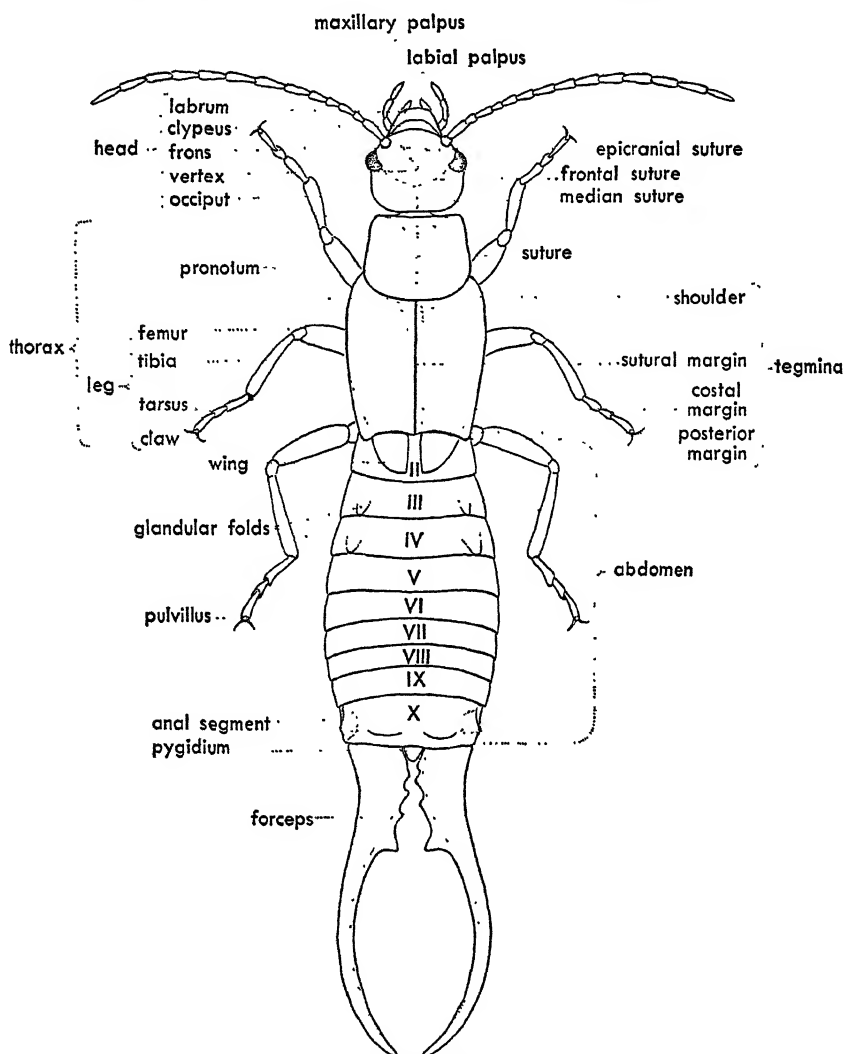


Fig. 53. European earwig, *Forficula auricularia* Linn. Dorsal aspect of male.

males differing from the females in having the forceps larger and curiously formed. A great deal has been written concerning the use of these forceps, and it appears certain that they are employed for purposes of defense,¹ for captur-

¹ Concerning this point, "Gadeau de Kerville was nipped by *F. auricularia* so strongly that

ing and killing prey, and to a lesser extent in the folding and unfolding of the wings. The females are oviparous, laying large numbers of smooth, oval eggs, which in some species are white, in the damp soil, manure, refuse, or anywhere that the insects occur in nature. In the temperate regions the eggs are often laid in late winter or early spring and hatch soon after deposition. Maternal care of the eggs and young by the females has been observed for many years. Multiplication is often very rapid, and earwigs may become a serious nuisance indoors and a pest in the garden. There are from four to six molts from the first-born to the adult. In cooler regions there is but one generation a year, while in the tropics reproduction and development go on unabated.

The abdomen is well developed and is composed of nine distinct and two indistinct segments in the male and seven distinct and two indistinct segments in the female. In the former the first tergum is fused with the metathorax and the 11th is represented by a small pygidium. In the latter the eighth and ninth segments in front of the terminal segment are hidden by the seventh. These terminal segments in certain forms are designated as *opisthomeres*. They comprise a small horny plate projecting downwards from the 10th segment above the anus, representing the supra-anal plate or pygidium, the metapygidium, and the telson, which are much used in classification. The forceps are modified cerci or uropods, as evidenced by the fact that in several species the immature stages bear many-segmented cerci much longer than the body. These cerci are reduced to a single pair of typical forceps with the last molt (Fig. 53). The forceps occur in a wide variety of shapes and sizes and are conspicuous in all species. They may be simple or armed with teeth and protuberances on the inner surfaces which have some taxonomic value. If the 10th sternite is carefully removed, it will be found to have on the anterior margin a manubrium, a small membrane supported by a hardened band, which is of unknown use. There is also exposed the male genital organ or penis which may be easily removed and mounted for study, it being of great value in classification. The hidden sternites, the paraprocts, and the opisthomeres are likewise exposed to view and the latter may be removed and mounted on points or microscopic slides for study. There are two pairs of spiracles on the thorax and seven pairs on the abdomen (Westwood, 1839).

Earwigs and arixenids comprise a very small order of about 1,050 described species and reach their maximum development in the tropics with gradually decreasing numbers towards the cooler limits of the temperate regions.

KEY TO SUBORDERS

1. Compound eyes much reduced; inner margin of the mandibles densely
bristled; forceps feeble and hairy; body hairy; on bats or in bat
caves **ARIXENINA** p. 137

blood was drawn, and Commander J. J. Walker had the same experience in New South Wales, from the largest known earwig, *Anisolabis (Titanolabis) clossea*" (Burr, 1910).

P. Rau, in *The Jungle Bees and Wasps*, 1933, has this to say about the Panama species, *Psalis americana* Beauv.: "This earwig has a pair of forceps on the rear of the body which are used with such astonishing efficiency that the creature is likely to gain its freedom whenever it uses them."

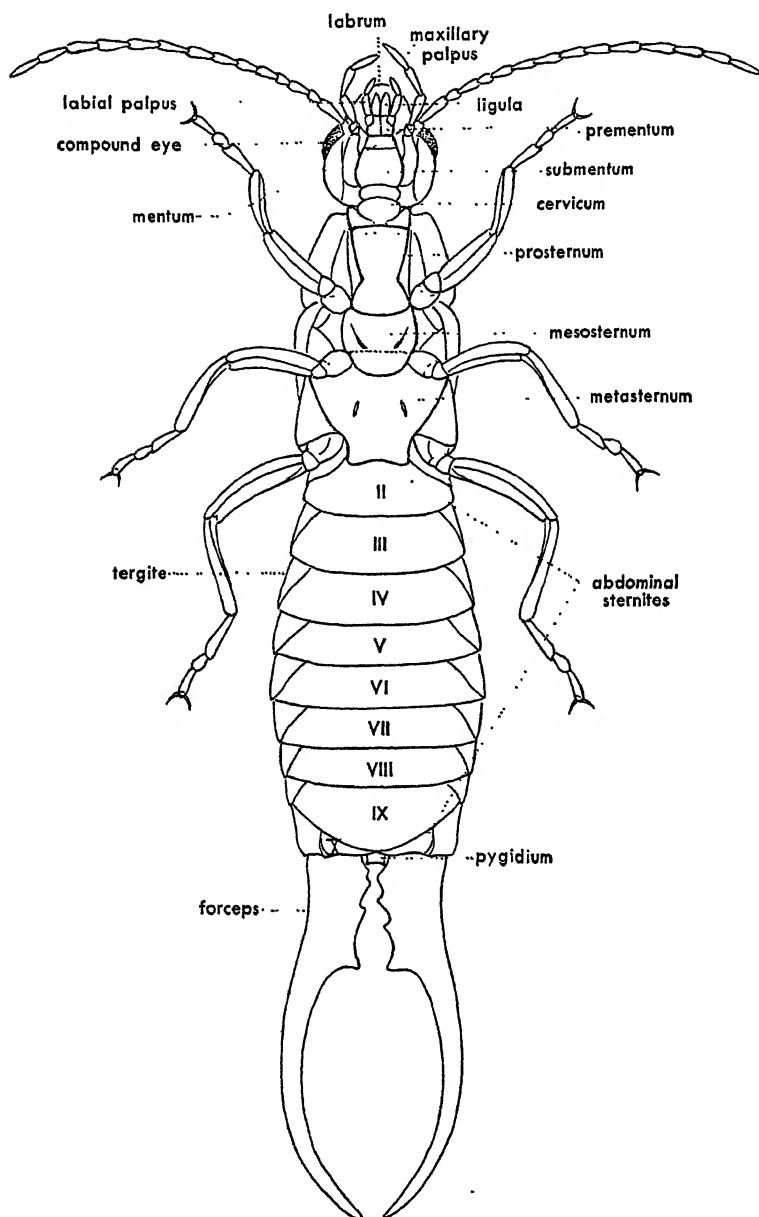


FIG. 54. The European earwig. Ventral aspect.

2. Compound eyes well developed; inner margin of the mandibles normal, not bristly; forceps strongly developed, chitinized, smooth; body smooth **FORFICULINA** p. 138

Suborder ARIXENINA Burr 1913

Family ARIXENIIDÆ Jordan 1909 (Ar-ix'en-i'i-dæ, from the Greek Ἄρειος, devoted to Ares, war-like, martial, + ξένος, a foreigner, stranger).

The two known species of this family are very peculiar indeed and hardly fit into the otherwise homogenous order DERMAPTERA, from which they will

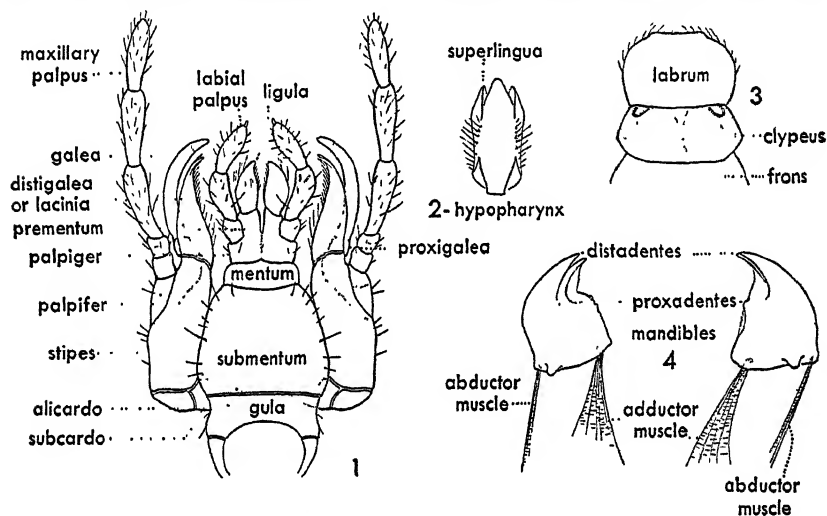


FIG. 55. The European earwig. Mouth parts. 1, ventral aspect; 2, hypopharynx; 3, labrum; 4, mandibles.

doubtless be separated in the course of time. They are small, wholly apterous, hairy, flattened creatures scarcely more than 21 mm. in length. They have been taken in association with tropical bats, either as ectoparasites or as inhabitants of a bat cave. The head is somewhat cordiform. The mandibles are flattened, the inner margins densely studded with short stiff bristles, and terminate in two stout teeth. The inner lobe of the maxilla is also bidentate, and the hypopharynx is trilobed. The compound eyes are small or vestigial, and the ocelli are wanting. The antennæ are prominent and 13-segmented. The legs are short and strong and permit of rapid crawling. The tarsi are three-segmented, the first and second short and the third long. The 11-segmented abdomen terminates in a pair of single-segmented cerci or forceps which are hairy and are somewhat curved as in the earwigs. This similarity gives the ARIXENIIDÆ their chief claim to relationship with the earwigs. There are 10 pairs of spiracles, two on the thorax and eight on the abdomen. The crop is

long and the gut has three convolutions. The Malpighian tubules are arranged in two large groups. There are 11 ganglia in the main chain. The young are born alive.

Arixenia esau Jordan, the first species to be described (in 1909), was found in the gular pouch of the large naked bat, *Cheiromeles torquatus* Horsfield, on the Sunda Islands of the Malay Archipelago.

Arixenia jacobsoni Burr (1912) was collected in a bat cave near the seashore at Babakan, Java. Concerning its occurrence there, Burr and Jordan (1913) give the following very interesting statement: "The most conspicuous insects inhabiting the cavern are, however, the earwigs mentioned above; they crawl in countless numbers on the surface of the guano and everywhere on the rocky walls. Evidently they live on the various larvæ feeding on the guano, but besides this they are constantly waging a terrible war against each other, the victors devouring the bodies of their slain mates. Especially those which have just moulted, their skins still being soft and of a yellowish-white color, are hunted down by those in a more advanced state of maturity. . . .

"A more loathsome spectacle than these thousands of ugly, hairy creatures running about hither and thither, fighting and devouring each other can hardly be imagined."

Suborder FORFICULINA Newman 1834

For'fi-cu'li-na, from Latin *forfex*, shears.

KEY TO FAMILIES¹

1. Metapygidium and telson present as distinct hardened plates; or else they are lost in the pygidium when it is fused with the 10th tergite to form a squamopygidium or anal process; pygidium without processes; male genitalia double 2
 Metapygidium and telson degenerate; pygidium small but well developed, often with processes; male genitalia single 4
2. Squamopygidium rarely present; opisthomeres (pygidium, metapygidium, and telson) distinct; body normally depressed; forceps rarely sickle-shaped 3
 Squamopygidium always developed; body strongly depressed or flattened; forceps sickle-shaped and without teeth **APACHYIDÆ** p. 139
3. Metapygidium and telson not reduced, but nearly as large as the pygidium; femora compressed and keeled **PYGIDICRANIDÆ** p. 139
 Metapygidium and telson greatly reduced and much smaller than the pygidium; femora not compressed or keeled **LABIDURIDÆ** p. 140
4. Second tarsal segment lobed or dilated 5
 Second tarsal segment simple, neither lobed nor dilated **LABIIDÆ** p. 142
5. Second tarsal segment with a narrow lobe extending beneath the third **CHELISOCHIDÆ** p. 142
 Second tarsal segment lobed or dilated **FORFICULIDÆ** p. 143

¹ There is much latitude exercised by various authors regarding the classification of the true earwigs. They may be arranged in from three to 30 or more families, which indicates the present confusion concerning the group.

According to Blatchley (1920), there were only 15 species known at that time to be native to or introduced into North America north of Mexico. Twelve species occur in the northeastern part and one species in Canada. However, the number of foreign species is gradually increasing.

Family APACHYIDÆ Verhoeff 1902

(A-pach'yi-dæ, from Greek *ἀ*, not, + *παχύς*, thick, large, fat).

Often brightly colored earwigs with flattened or depressed bodies; 30- to 50-segmented antennæ; elliptical pronotum; well-developed, smooth tegmina which expose the scutellum; long, ample wings; compressed, carinated or keeled femora; first tarsal segment short and thick, second very minute, third slender and longest; empodium present; penultimate ventral segment produced posteriorly into a long, slender, pointed process; forceps similar in both sexes, sickleshaped and without teeth. The members of this family form a primitive group occurring in all of the tropical regions except Australia. They live under the bark of dead trees and similar secluded places. *Apachyus feæ* Bormans is a common species of southern Asia.

Family PYGIDICRANIDÆ Verhoeff

1902 (Py-gid'i-cran'i-dæ, from the Greek diminutive *πυγίδιον*, a little rump, a thin rump, + *κράνιον*, the skull. Perhaps calling attention to the fact that the pygidium is shaped somewhat like a head?)

The members of this family predominate in the oriental regions. They are large and powerful earwigs. The antennæ have 15 to 30 segments, the third segment longer than the fourth and fifth, the basal segment keeled above; mostly

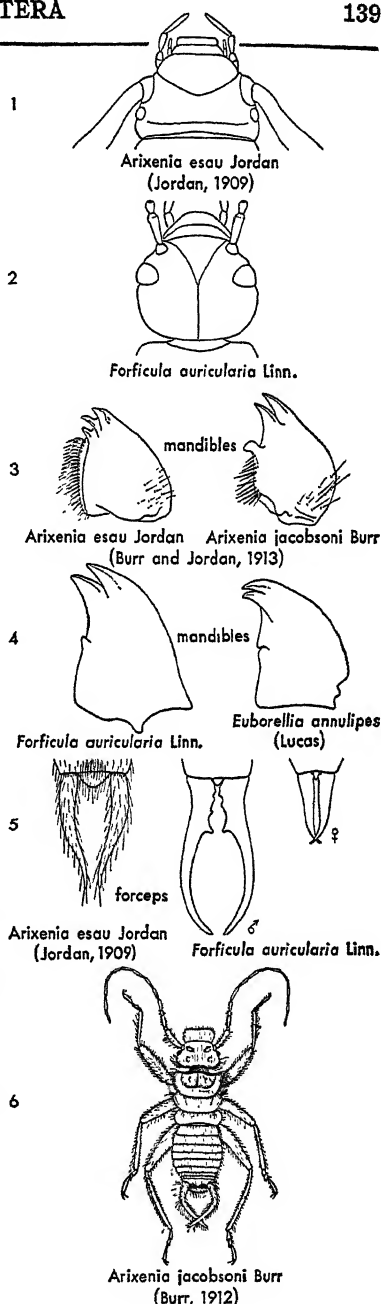


FIG. 56. DERMAPTERA. Drawings showing some important characteristics.

winged forms with a few apterous; the tegmina weakly attached, exposing the scutellum when closed; abdomen cylindrical, more or less dilated.

Diplatys gerstaeckeri Dohrn (*Dyscritina longiselosa* Westwood) is perhaps the most interesting member of this family and one of the most remarkable earwigs. The immature forms have long, many-segmented cerci, resembling those of certain thysanurans and varying with the size and age of the nymph. Very young individuals 2.5 mm. long have cerci 2.5 mm. long, consisting of 14 segments. Half-grown young, 4.5 mm. long, have cerci 10 mm. long and 43-

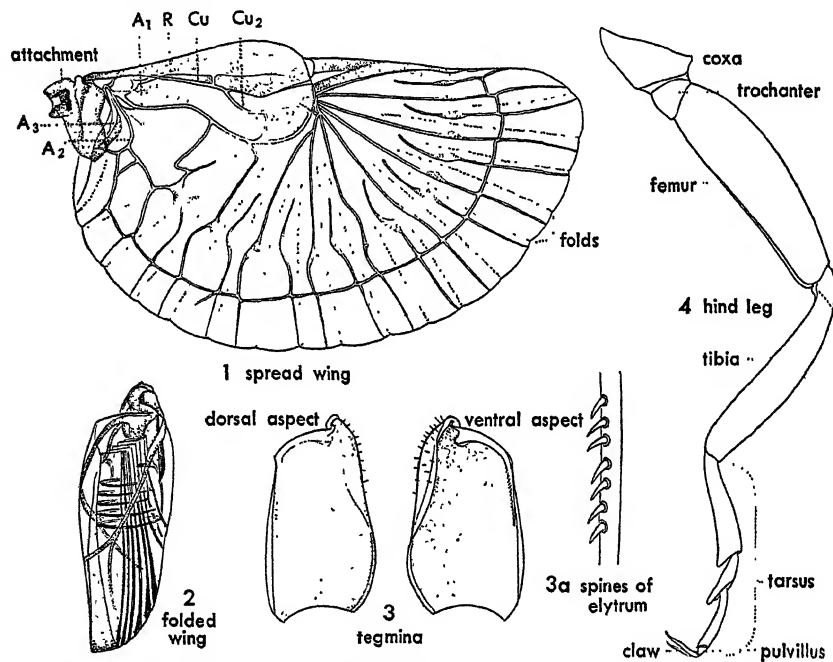


FIG. 57. European earwig. 1, wing spread, 2, wing folded; 3, tegmina; 4, hind leg.

segmented. The last-instar nymphs, 7.75 mm. long, have cerci 13.5 mm. long which are 45-segmented. In the adult, which may be 9 mm. long, the cerci are replaced by a pair of true forceps 1 mm. long. Other closely related species have a similar remarkable development. The adults are somewhat reddish in color. It occurs in Ceylon.

Family LABIDURIDÆ Verhoeff 1902 (Lab'i-dur'i-dæ, from the Greek *λαβίς*, *λαβίδος*, a holder or forceps, + *ούρά*, a tail).

Earwigs with normal or somewhat flattened bodies; antennæ with 15-25 segments; winged and apterous; pygidium practically invisible from above but from behind appearing as a vertical triangular plate with the apex pointing downwards.

This family contains the largest known earwig, *Titanolabis clossea* Dohrn, a stout, black, wingless, Australian species which may attain a length of 40 mm, almost double the normal size. The family also contains the three following cosmopolitan species:

- (1) *Labidura riparia* (Pallas), a brown and black winged earwig, often 25 mm.

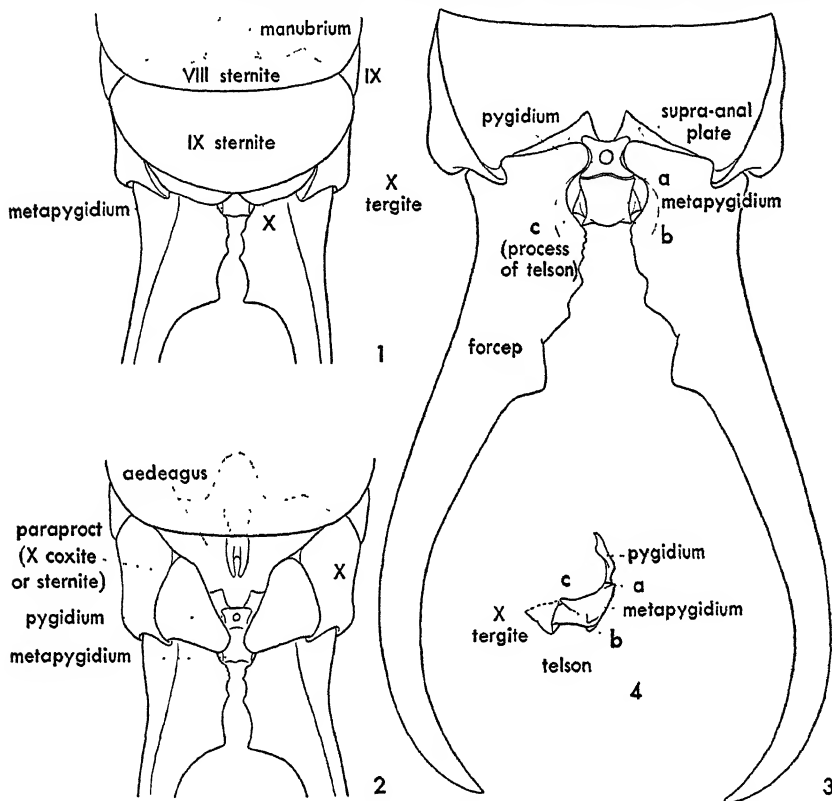


FIG. 58. Male genitalia of the European earwig. 1, ventral aspect; 2, same with ninth sternite removed; 3, same with ninth sternite and paraprocts removed; 4, lateral aspect of the opisthomeres or the three segments of the supra-anal plate.

long and common in India and Hawaii but also present throughout the north subtropical and temperate regions.

(2) **The maritime or seaside earwig**, *Anisolabis maritima* (Gene), a dark-brown apterous species, 18–24 mm. long, with pale legs. It inhabits ocean beaches just above the highwater mark and hides under stones, logs, and debris, not being at all adverse to swimming in the water. It forages along the water's edge and occurs on both the Atlantic and Pacific seashores of the United States, having been introduced from the Old World.

(3) The spotted or ring-legged earwig, *Euborellia annulipes* (Lucas) (*Anisotabris*), a wingless, dark-brown or blackish species with one or two white segments near the tips of the antennæ and darker spots on the legs. It is 9-11 mm. long, and the right member of the forceps in the male is more incurved than the left. This species occupies probably the widest climatic range of any earwig in the world and occurs in both the tropical and temperate regions. It frequents damp and wet places along waterways and hides during the day under stones, logs, and trash. It may occur in great numbers in manure piles, as was recently observed in the San Francisco Bay region of California. It is abundant in the plains of India and is numerous along the Gulf of Mexico and the central and south Atlantic seaboard of North America and in Hawaii, and it also occurs in much of Europe, Central and South America, and southern Asia. It occasionally enters houses but does not appear to be either a household or a garden pest as it seems to prefer animal food.

Family LABIIDÆ Burr 1909 (La-bi'i-dæ, from the Greek *λαβίς*, *λαβίδος*, holder or forceps, tongs).

A rather large, heterogenous family which might appropriately be separated into a number of natural families and has been by some writers. The body is normally or strongly flattened; the antennæ with 10 to 20, not more than 25, segments; the femora compressed, the second tarsal segment cylindrical as are also the other segments.

This family contains two cosmopolitan species, the small earwig, *Labia minor* (Linn.), and the chief earwig, *Prolabia arachidis* (Yersin), both of which have been carried in ships to various parts of the world. The former is a small black species only 4-6 mm. long. It now occurs along the Atlantic, Gulf of Mexico, and Pacific coasts of North America and is the only earwig recorded in Canada. It is common in many parts of the Old World and particularly in India, where it flies readily.

Family CHELISOCHIDÆ Burr 1907 (Chel'i-so'chi-dæ, from the Greek *Χελος*, lip, labrum, or from *Χηλή*, claw, + *ισος*, equal, the final "s" being changed to "ch" for euphony).

Medium-sized to large earwigs with bodies stout or robust and somewhat depressed; reddish, dark brown, or black in color, often with a metallic luster; wings usually well developed, some forms apterous; tegmina perfect or abbreviated; legs short and stout, often compressed; second tarsal segment narrow and terminating in a rather wide lobe which is produced beneath the third segment. This family is well represented in the Old World tropics.

The black earwig, *Chelisoches morio* (Fabricius), is now nearly a cosmopolitan species, probably originating in oriental Asia and distributed through commerce. It is a large species 25 mm. long and is polished black with the apical portions of the legs pale and one or two segments just beyond the middle of the antennæ also pale. It is the commonest species in the sugar-cane fields of Hawaii where it is predacious on the sugar-cane leaf hopper and its parasites as well as on other

insects. The adults fly readily and are able to fold and unfold the wings rapidly. It is occasionally taken in California.

Family FORFICULIDÆ Burr 1907 (For'fī-cu'li-dæ, from Latin *forficula*, a pair of small shears or scissors).

This is an important large family of earwigs which contains the most highly developed species and some of the most widely distributed and destructive forms. The body is convex, cylindrical, or strongly depressed; the antennæ have 12 to 15 segments, the fourth segment equal to or shorter than the third; winged or apterous but wings usually present; legs short and somewhat compressed; abdomen usually parallel-sided but may be dilated in the middle or posteriorly; forceps flat or cylindrical; well represented in the Palæarctic region.

In this family is to be found the well-known **European earwig**, *Forficula auricularia* Linnæus (Figs. 53–58), which is the most widely distributed species in the subtropical and temperate regions of the world and which is often a very troublesome household and garden pest that is known to occur in Europe, South Africa, Australia, New Zealand, South America, and North America. It is a shining, brown and black, winged species, 11–15 mm. long, which lives in moist or rather dry conditions, particularly in centers of population where it is likely to breed in enormous numbers in garbage dumps, manure piles, lawn cuttings, leaves, and decayed vegetation or debris of any kind. The pearly-white oval eggs are laid in small masses of from 10 to 25 in the wet soil or in or under debris, usually in mid-winter in the warmer sections and in early spring in the colder limits of its distribution. There is but one generation a year. This species has widely varied feeding habits. In the Mediterranean region it appears to be largely predacious on fly maggots and other scavengers and is considered beneficial, while in the cooler areas it still seems to prefer a vegetable diet and attacks many kinds of growing plants, although it feeds to a considerable degree upon animal matter, both dead and alive. It is perhaps most noxious as a pest in households, where its nocturnal habits are similar to those of cockroaches.

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CHAPTER XIV

11. Order DIPLOGLOSSATA¹ Saussure 1879

(Dip'lo-glos'sa-ta, from the Greek διπλός, twofold, double,
+ γλῶσσα, tongue.)²

Hemimerids.

Very small, depressed, apterous insects covered with short hairs; with biting mouth parts; simple metamorphosis; atrophied eyes; and body terminating in a pair of long, unsegmented cerci.

These small insects, only 8-10 mm. long, belonging to the single family, HEMIMERIDÆ, constitute the smallest known order of insects at the present time, there being but two described species. The head is orthognathous with the mouth directed downwards. The mandibles are concealed by the maxillæ, the inner margins of which are dentate, and the maxillary palpi are five-segmented. The ligula is divided. The labial palpi are three-segmented. The prothorax is larger than the mesothorax or the metathorax. The legs are rather short, and the three-segmented tarsi terminate in a pair of claws. There are 11 abdominal segments, the eighth and ninth terga being so greatly reduced that they are invisible without dissection. There are two thoracic and eight abdominal spiracles; three thoracic and six abdominal ganglia; about 20 Malpighian tubules arranged in four groups; testes, a pair of follicles with two openings into the penis. There are 10 to 12 ovarioles. "According to Heymons (1912) a maternal placenta is present in *Hemimerus* and envelops the embryo. . . . The embryos, to the number of about six at a time, are nourished *in situ* within their respective ovarioles until they develop into young insects and are ready for birth" (Imms, 1934).

Family HEMIMERIDÆ Krauss 1900 (Hem'i-mer'i-dæ, from the Greek ἡμι, half, + μερίς, μερίδος, division, part).

Hemimerus talpoides Walker, the first species described in 1871, was taken as an ectoparasite on rats in Sierra Leone, Africa. Later, in 1909, specimens were found on one of the giant Gambian banana rats, *Cricetomys gambianus* in the Botanic Gardens at Entebbe, Uganda, indicating that this species ranges

¹ These insects have most often been included in the ORTHOPTERA as a single family. They were placed in the order DERMODERMAPTERA by Verhoeff in 1902 and in the HEMIMEROIDEA by Heymons in 1915.

² The name "double tongue" refers to a supposed double labium; "*ectolabium* being the mentum or submentum, and his (Saussure's) *endolabium* the galeæ and lacinia, the labial palpi becoming duplicated by a misunderstanding" (Carpenter, 1909).

across tropical Africa. *Hemimerus hanseni* was described in 1895 by David Sharp from specimens collected in the Cameroons. These insects also occurred in considerable numbers on Gambian rats in the London Zoo in 1937.

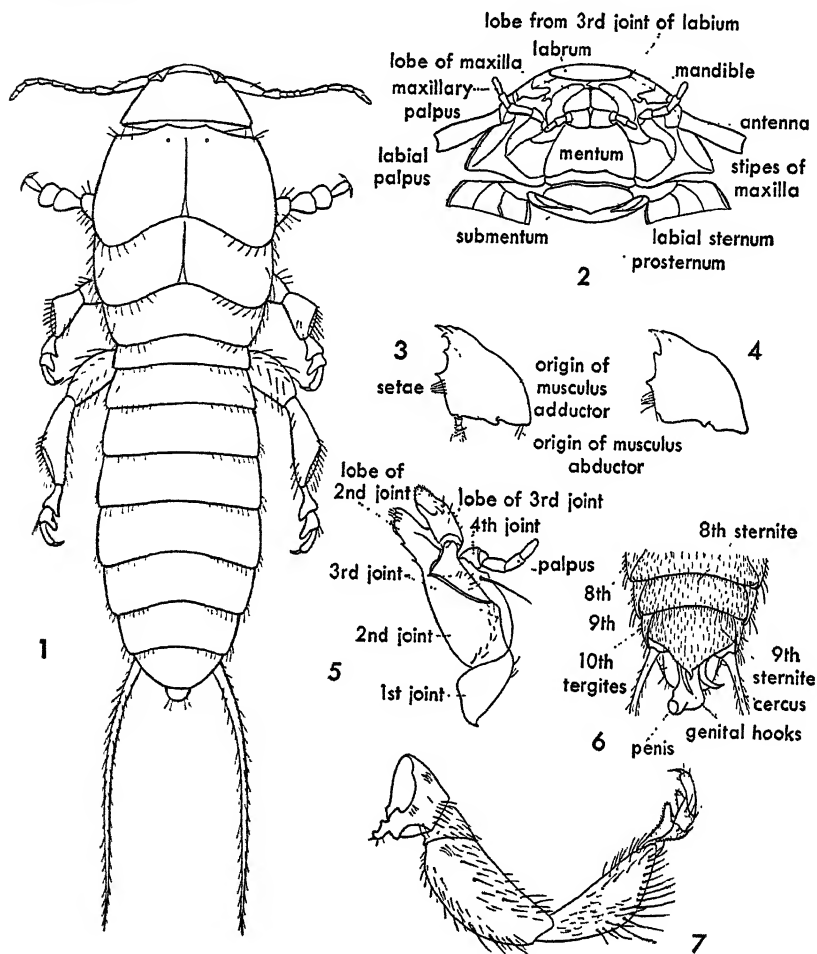


FIG. 59. *Hemimerus talpoides* Walker, a curious ectoparasite of the giant Gambian banana rat of Africa. 1, oviparous female; 2, ventral aspect of mouth parts; 3 and 4, mandibles; 5, left maxilla; 6, genitalia of male; 7, hind leg of female. (After Hansen, 1894-1895.)

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CHAPTER XV

12. Order PLECOPTERA Burmeister 1839¹

(Ple-cop'ter-a, from the Greek *πλεkein*, to weave, + *πτερά*, wings; referring to the wings overlapping the sides of the body.)

German, Uferbolde, Uferfliegen. French, La perle.

Stoneflies, Salmonflies, Perlids.

Medium-sized to large, elongated, somewhat flattened, soft-bodied insects; head broad; antennæ long, filiform with 25 to 100 segments; with two, three or no ocelli; compound eyes moderate to small; biting mouth parts with mandibles well formed or reduced. Two pairs of equal, many-veined wings, hind pair with large anal area often interrupted by a marginal incision; folded closely over the back in repose. Legs well developed, coxæ small, tarsi three-segmented terminating in two claws and an empodium. Abdomen 11-segmented, last segment reduced and with long filiform multi-segmented or few or single-segmented cerci. Simple or hemimetabolous metamorphosis. Immature stages or naiads aquatic, the general form, antennæ, and cerci similar to adult; with or without specialized respiratory gills.

Stoneflies are the most primitive of winged insects and are thought to be closely related to the ORTHOPTERA because of the greatly enlarged anal areas of the hind wings and the long many-segmented antennæ. They differ, however, in the texture and venation of the wings, in the poorly developed mouth parts, and the smaller coxæ.

Their geological history is very imperfectly known. The oldest known relatives of the PLECOPTERA are the PROTOPERLARIA Tillyard which differ from present forms in having well-developed pronotal expansions to the prothorax and both main branches, MA and MP, of the median vein. They resemble modern species in having cerci and similar wings, in which R_s and MA of the hind wings are partially fused. The absence of the median caudal filament is also in keeping with certain existing primitive forms. These archaic relatives were taken from the Lower Permian in Kansas and North Russia. The earliest known true stoneflies have been discovered in deposits of the Middle Jurassic in Siberia.

Stoneflies are aquatic insects, the immature forms of which inhabit rapid streams and the wave-swept rocky shoals of lakes and ponds, and the adults of which often occur in great numbers along the shores of their breeding places. The adults vary in color, form, and size and measure from $\frac{1}{2}$ -2 $\frac{1}{2}$ in. in length.

¹ The name of this order has not yet become fully stabilized. Linnæus placed the stoneflies in the NEUOPTERA in 1758. Latreille, in 1802, created for them the name PERLIÆ, by which designation they have become known in some modern works. Other important terms employed are: PERLARIDES Leach 1815; NEMURÆDES Billberg 1820; PERLIDÆ Stephens 1836; and PERLOIDEA, PERLARIA, Handlirsch 1903.

All forms are cryptically colored to match their surroundings. The colors are for the most part somber, being various shades of black, gray, brown, dull red, yellow, and pale green. Members of the Tasmanian genus *Eusthenia* have beautiful red hind wings bordered with purple. *Eustheniopsis venosa* Tillyard of Australia has purple hind wings, while the large black *Thaumatoperla robusta* Tillyard of the same continent has a bright-orange pronotum. They are slow and erratic fliers and seldom wander far from their breeding places. Rather they are to be found resting upon stones, logs, grasses, shrubs, and trees along the margins of streams, lakes, and ponds and are often exceedingly numerous in certain hilly and mountainous regions where swift running water and rocky bottoms are available. The eggs are laid directly in the water and in some cases are extruded in a sac which is carried by the female before final deposition. They are frequently very small and are laid in astonishing numbers of 5,000 to 6,000 per single individual. The nymphs or naiads live under debris in eddies or under stones in clear, well-aërated fresh water. Although apterous, they look remarkably like the adults. Tracheal gills in the form of tufts or paired lateral filaments occur on the first five or six abdominal segments or are arranged as a rosette around the anus, or they may be entirely lacking in which case respiration occurs through the rectum. After a number of molts the wing-sheaths develop, and with the final metamorphosis the naiads leave the water and cling to stones, logs, roots, and shrubbery along the waterways and the adults emerge through a longitudinal slit in the dorsum of the thoracic region, leaving the empty skins as mute evidence of their having forsaken the water for a life of aërial freedom. The immature forms feed largely upon the larvæ of mayflies, midges, and other small aquatic animals, but some at least are thought to feed upon the vegetable debris that collects along the bottom. The larger forms are formidable predators, and, though most nymphs are slow, some are remarkably agile. All stages are in turn consumed by fish and form a considerable part of the diet of trout and other game fish. The adults often issue during the fall, winter, and early spring when it is necessary to leave the water through cracks and crevices of the ice. According to Frison (1929), "At least ten species of stoneflies in Illinois respond to cold weather in this way. To anyone not well acquainted with our fall and winter fauna, it is a startling revelation to see such large insects sprightly climbing up tree trunks in search of food when temperatures are near or below freezing, or to watch them crawling over the ice and snow which partly holds in its embrace the waters that nurtured their infancy."

The adults appear to feed but little. Certain species are herbivorous and feed upon the leaves of plants growing within their scope of activities.

External Anatomy. — The most important features of the external anatomy are already enumerated and are shown in the accompanying illustrations. There are normally three ocelli of which the median is smallest, but there may be only two in *Neoperla* and *Peltoperla*, or none at all. The mouth parts of many of the species of the northern regions are greatly reduced. In the PERLIDÆ the mandibles are normal, but in the others they are poorly developed. Representatives in the Southern Hemisphere have strong mouth parts and are largely

carnivorous. The maxillary palpi are five-segmented and quite variable. The labium is four-lobed and the labial palpi are three-segmented. The thoracic

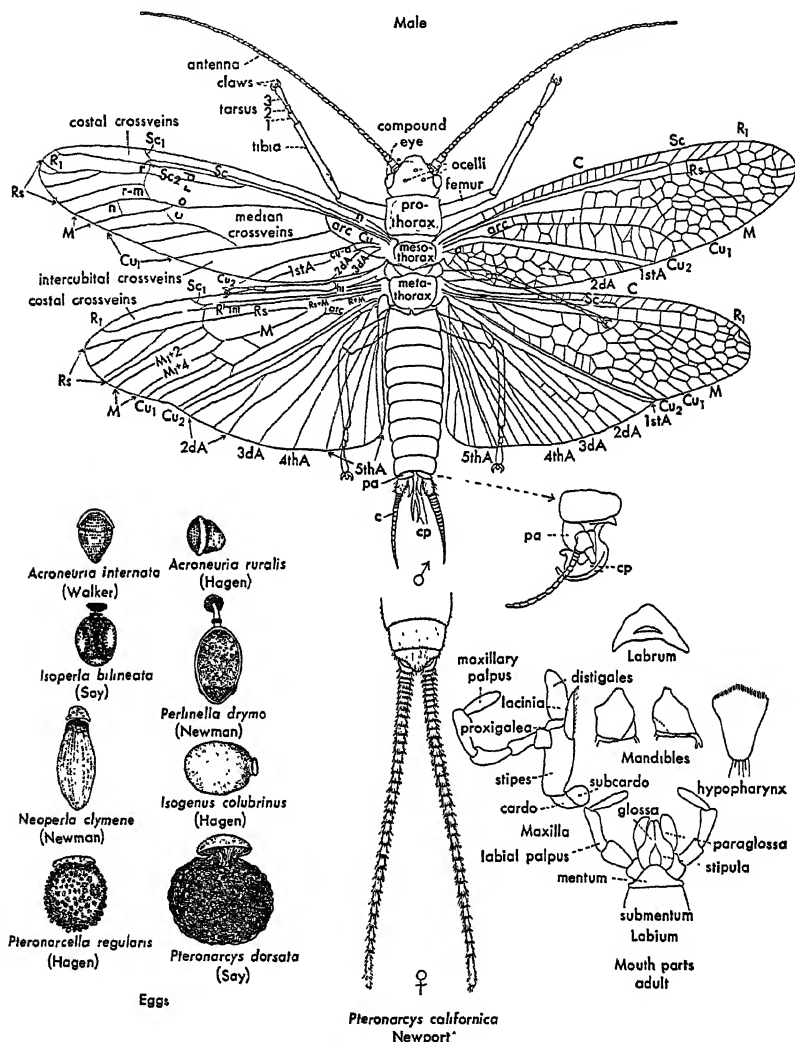


FIG. 60, part A. Stoneflies or PLECOPTERA. Important characteristics of adult, eggs and mouth parts. (Eggs redrawn from Needham and Claassen, 1925.)

segments are well defined, with a primitive arrangement of the sclerites. The legs are long and strong, the femora flattened laterally to offer little resistance to swift currents, and the three-segmented tarsi bear a pair of strong claws. The

relative lengths of the tarsal segments are used in separating certain of the families and genera. The wings are membranous, the fore pair usually being long and narrow and a hind pair much wider owing to the large anal area, which is often as large, or nearly as large, as the rest of the wing. The anal area is set off by two large veins Cu_2 and 1A and often by an incision on the margin at the extremities of these veins. Between the longitudinal veins in the more primitive EUSTHENIIDÆ there occurs a fine network of veins designated by Tillyard as *archedictyon*, which are wholly absent in the higher forms. A great deal of uncertainty exists as to the proper nomenclature of the venation because of the discovery of certain fossil forms which have thrown new light upon the ancestry and derivation of the whole wing structure. The anal area or lobe folds longitudinally against the sides of the body and the remainder of the hind wings is folded over the back. All are covered by the fore wings in repose. In certain of the species like *Isogenus nubecula* Newman and *Perla maxima* Scopoli of North Britain the wings of the males are so reduced as to be useless for flight.

The abdomen consists of 11 segments, the last being greatly reduced in size and bearing long multi-segmented, few-segmented, or one-segmented cerci. There are two pairs of thoracic and eight pairs of abdominal spiracles. On the ninth abdominal sternite of the males of several genera there is a disk-like percussion hammer used for drumming on the surfaces upon which the insects rest. In buildings this noise may be quite audible at night and has been noted for many years. Macnamara (1926) states: "A typical performance, which I noted down at the time, took place between ten and eleven o'clock on the night of the 11th of July, 1924. It was a rapid tattoo, the beats almost running into one another: 'g-r-r-r-r-r', continued for about three seconds, a pause of about two seconds and a short 'g-r-r' of about one second. This 'phrase' was repeated six or seven times in the course of ten or fifteen minutes. On other occasions the noise was a single 'g-r-r-r-r' for two or three seconds without the pause and short repetition."

Internal Anatomy. — The internal structures are known for certain genera only, and therefore only fragmentary data are available for a general discussion of such organs. The oesophagus is very long and large, and the gizzard is greatly reduced or absent. In each sex the pair of principal glands are connected, the testes of the male and the oviduct and egg tubes of the female forming arches. The eggs are peculiar in that they possess a micropyle with a transparent cover, and in some there is a series of canals on the chorion as in *Perla maxima* Scopoli. Some notion of the different organs may be gained by comparing the two common genera, *Pteronarcys* and *Perla*. In the former the oesophagus is very long; the gizzard rudimentary or absent; the mid-gut small; with three thoracic and eight abdominal ganglia. In the latter there are 10 anterior enteric cæca, the lateral pair the largest; hind intestine short; Malpighian tubules varying from 20 to 60; a pair of salivary glands present; both supra- and infra-oesophageal ganglia small; and with only six abdominal ganglia.

The order is world-wide in distribution, being more or less restricted to the

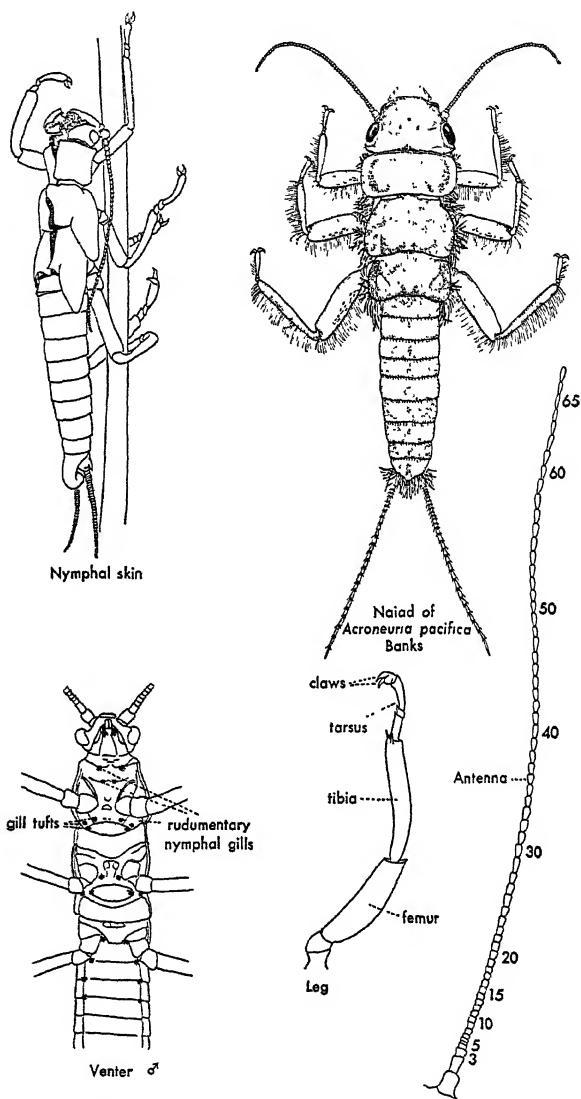


FIG. 60, part B. Stoneflies or PLECOPTERA. Naiad, cast skin or exuvia, ventral side, leg of same, and antenna of adult. (Naiad after Claassen, 1931.)

temperate, the arctic, and the antarctic regions. There are approximately 100 genera and 1,260 species described.

Handlirsch (1925) groups all the members into a single family, PERLIDÆ, and six subfamilies: TÆNIOPTERYGINÆ, NEMOURINÆ, PERLINÆ, PTERONARCINÆ, GRIPOPTERYGINÆ, and CAPNIINÆ. Ordinarily, however, five or seven families are recognized as follows: PTERONARCIDÆ, NEMOURIDÆ, PERLIDÆ, CAPNIIDÆ, AUSTROPERLIDÆ, EUSTHENIIDÆ, and LEPTOPERLIDÆ. The last three Australasian families are often combined in the single family GRIPOPTERYGIDÆ. The TÆNIOPTERYGIDÆ may also be set apart from the NEMOURIDÆ as a separate family.

KEY TO FAMILIES OF NORTHERN HEMISPHERE¹

ADULTS

1. Anal area of fore wing with two or more full rows of cross veins

PTERONARCIDÆ p. 154

 Anal area of fore wing either with no cross veins or, if they are present, with but one row 2
2. Cerci one-segmented or much reduced NEMOURIDÆ p. 156
 Cerci many-segmented and well developed 3
3. Fore wings with a series of median and cubital cross veins; radius and media are incompletely fused and separate gradually at the base except in small greenish-colored forms PERLIDÆ p. 156
4. Fore wings with only one or two median and one cubital cross vein; radius and media are completely fused at base and separate at a rather sharp angle. CAPNIIDÆ p. 157

NAIADS OR NYMPHS²

1. Gills visible 2
 Gills invisible. 4
2. Gills under the thorax and first two or three abdominal segments (prothorax wider than head, ligula four-lobed; mostly large dark-brown nymphs; herbivorous) PTERONARCIDÆ p. 154
 Gills only on the thorax. 3
3. Gills on the underside of the prothorax (a pair either at the throat or as single filaments at the base of each coxa; hind wing pads diverge outward from the body except in *Leuctra*, where they are long and narrow and lie parallel to the body; and labial palpi extend far beyond tip of ligula) (in part) NEMOURIDÆ p. 156
 Gills on all three thoracic segments arranged as filamentous tufts on the sides; legs densely fringed with long hairs (first and second tarsal segments very short, subequal, together less than half as long as third; labrum three to four times as wide as long; labial palpi slender and extend far beyond tip of the labium, which is two-lobed; mandibles

¹ After Needham and Claassen (1925, p. 31).

² After Claassen (1931) and other sources.

- slender; body mostly flattened, strikingly colored; carnivorous) (in part) **PERLIDÆ** p. 156
4. Palpi with apical segments more slender than the basal ones (in part) **PERLIDÆ** p. 156
- Palpi with apical segments as wide as the basal ones 5
5. Second segment of tarsus much shorter than either the first or third (in part) **NEMOURIDÆ** p. 156
- Second segment of tarsus not so short 6
6. Third segment of tarsus not longer than the combined first and second; cerci glabrous, as long as the body (in part) **NEMOURIDÆ** p. 156
- Third segment of tarsus twice as long as the first and second together (labial palpi never reach beyond the tip of the ligula) . . . **CAPNIIDÆ** p. 157

Family PTERONARCIDÆ (Jacobson and Bianchi 1905) Enderlein 1909
(Pter'o-nar'ci-dæ, from the Greek *πτερά*, wings, + *νάρκη*, stiffness, stupor; referring to their sluggishness and slow flight). Stoneflies, Salmonflies.

The adults of this small family including the largest species are characterized by reticulate venation in the fore wings extending across the length of the anal veins; dusky or clouded wings; mandibles rudimentary; palpi apparently distinctly many-segmented owing to numerous irregular reticulations; middle segment of the tarsus half as long as the basal segment; supra-anal process of the male greatly developed; and the 10th abdominal segment of the male very much reduced. In the naiads the mandibles are stout and toothed at the apex and the gills are arranged in pedicellate tufts on the ventral side of the anterior region of two or three terminal segments, rudiments of which are carried over into the adults.

The giant stonefly, *Pteronarcys dorsata* Say, is the largest known species, attaining a length of 40–47 mm. to the wing tips in the male and 50–60 mm. in the female. The color is dark brown with yellowish venter, intersegmental and leg markings. The naiads of this species inhabit debris in eddies below stony rapids in small rivers in the northern United States from Labrador to Maryland and westward to Alaska.

The California salmonfly, *Pteronarcys californica* Newport, is one of the most interesting western species. The length to the wing tips in the male is 33–40 mm. and in the female 41–46 mm. The color is dark grayish-brown marked with paler brown, reddish, and black shades. The wings also have blackish veins. This species inhabits swift, shallow parts of large and small streams, and the adults emerge in May, June, July, and August. It ranges from Kansas and New Mexico on the east into Washington and California on the Pacific coast. In California it often appears in great numbers along the upper reaches of the Sacramento River and its tributaries, particularly in the vicinity of Duns-muir, along the McCloud River near its confluence with the Sacramento, and on Burney Creek and the Pit River from Burney Falls to Fall River Mills. Recently built dams have greatly lessened its abundance in the Pit River where during early days the adults collected on the shrubbery along the banks in such numbers as to weigh down and even break the branches. The Indians shook

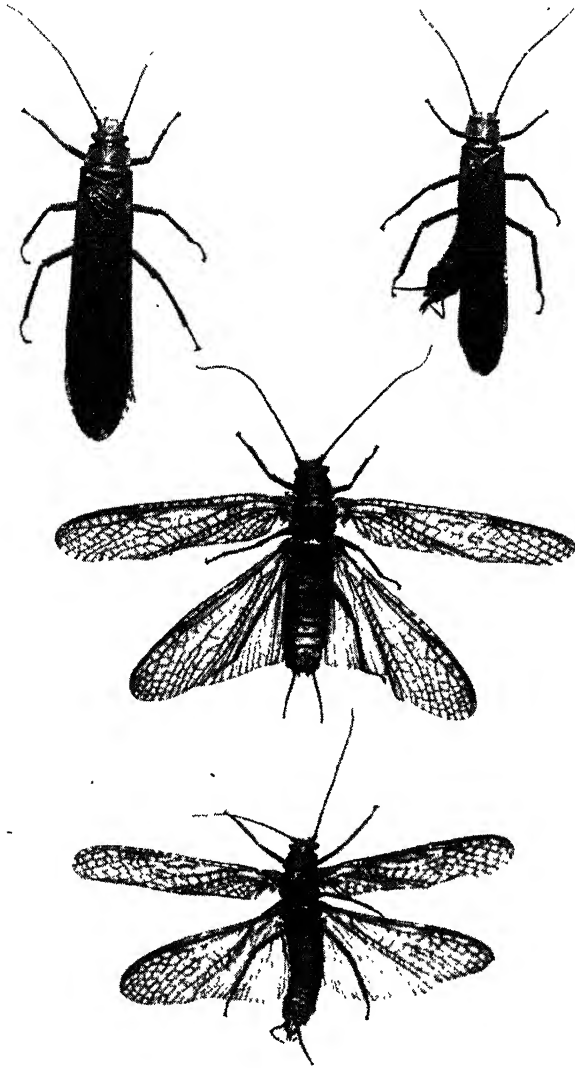


FIG. 61. The California salmonfly, *Pteronarcys californica* Newport. Females, upper left and middle; males, upper right and bottom. (From *A History of Entomology*.)

and otherwise dislodged them into the water and dipped them out in front of log booms, constructed across the streams for this purpose, to use them for food. In recent years the adults have been extensively used as bait by trout fishermen in those regions.

Pteronarcella badia Hagen, a blackish species 15–19 mm. long, is often taken on willows and other plants bordering streams in the Great Basin and north-western states.

Family PERLIDÆ (Latreille 1802) Stephens 1829 (Per'li-dæ, from the pearl and first given by Aldrovandus, 1602, to the dragonflies because of the roundness of the head "which rivals a pearl in brilliance and reflects images like a mirror").

This, the largest family of stoneflies in North America, consists of small green and yellowish species and quite large somber-colored forms which inhabit the borders of streams, lakes, and ponds. In some species the males are brachypterous. In the adults the apical segments of the palpi and the two basal segments of the tarsi are much reduced. There are two or three ocelli. The males are with or without the percussion disk on the ninth abdominal sternite. Many American species are included in 15 genera of which the most important are: *Perlodes* Banks, *Isogenus* Newman, *Perla* Geoffroy, *Alloperla* Banks, *Chloroperla* Needham, *Neoperla* Needham, *Isooperla* Banks, and *Acroneuria* Pictet.

Perla capitata Pictet, a brown and yellowish species, 16–24 mm., *Neoperla clymene* Newman, yellow and brown with infuscated wings and 10–18 mm. long, and *Perlesta placida* Hagen, brown to black with yellow markings and 9–14 mm. long, are the most widely distributed stoneflies in North America, occurring throughout the area east of the Rocky Mountains. *Alloperla borealis* Banks, a yellowish-brown and greenish species, 11–16 mm. long, is common throughout the Pacific coast region, and *Acroneuria pacifica* Banks, dark brown and yellowish and 32–58 mm. long, occurs generally west of the Rocky Mountains.

Family NEMOURIDÆ (Selys 1888) Klapálek 1905 (Nem-our'i-dæ, from the Greek νῆμα, thread, + οὐρά, tail; referring to the cerci). Thread-tailed Stoneflies.

A large family of imperfectly known stoneflies of world-wide distribution, in which the long tails or cerci are absent in the adults. In the genera *Nemoura* Latr., *Leuctra* Stephens, and *Perlomyia* Banks the cerci are one-segmented while in *Tæniopteryx* Pictet they may have from one to 10 segments. They have long, slender antennæ and three small ocelli (only two in *Tæniopteryx occidentalis* Banks). The tarsal segments are subequal or the second much the shortest. The second anal vein of the fore wing is forked. The colors are somber, mostly brown or black, and the species are small, usually less than 15 mm. in length.

Nemoura depressa Banks, a reddish-brown species, 7–10 mm. long, and *N. cinctipes* Banks, blackish-brown with banded legs and wings and 9–13 mm. long, are widely distributed western species. *Nemoura venosa* Banks, blackish-

brown and 7-7.5 mm. long, is known along much of the Atlantic seaboard. The species of *Leuctra* are more restricted in distribution. *Tænipteryx nivalis* Fitch, brown or black and 11-17 mm. long, and *T. fasciata* Burmeister, blackish and 10-15 mm. long, are common in the east while the Pacific salmonfly, *T. pacifica* Banks, brown or blackish with yellowish or reddish markings and 12-15 mm. long, and *T. occidentalis* Banks, black with spotted wings and 11-15 mm. long, are common western species. The Pacific salmonfly has been observed to feed upon the foliage of fruit trees and native streamside plants in the Pacific Northwest.

Family CAPNIIDÆ Klapálek 1905 (Cap-ni'i-dæ, from the Greek *καπνός*, smoke; because of the dusky colors). Smoky Stoneflies.

These are small, blackish stoneflies usually less than 12 mm. long which are distinguished by having the radius and media veins fused for some distance from the base and then branching at a wide angle; few- to many-segmented cerci; long antennæ; very short middle tarsal segment; three small ocelli; often abbreviated wings; hind wings with a large anal area; ventral appendage absent on the ninth abdominal sternite of the male; and the eighth abdominal sternite of the female not produced into a distinct subgenital plate. This is a small family comprising only three genera and 20 species in North America.

Capnia vernalis Newport, black and but 4.5-6.5 mm. long, occurs in the east, whereas all the rest of the known American species, as well as *Capnura venosa* Banks, the only temperate American representative of this genus, range west of the Rocky Mountains. The former has been reported in Canada by Sharp (1895, p. 405) as coming up frequently in the ice, where it casts its skin. The naiads are blackish.

All of the species of *AllocaPNia* occur east of the Rocky Mountains. Of these *A. pygmaea* (Burmeister), dark brown or black and only 3-7.5 mm. in length, is the best known. The naiads are black.

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CHAPTER XVI

13. Order ISOPTERA¹ (Brullé 1832) Comstock and Comstock 1895

(I-sop'ter-a, from the Greek *ἴσος*, equal, + *πτερά*, wings; referring to the equal wings.) German, Termiten. French, Termites.

Termites, White Ants.

Small to medium-sized, mostly soft-bodied and pale-colored social insects living in large concealed communities under a caste system; metamorphosis simple; head small to very large, free, heavily sclerotized; mouth parts typically biting or vestigial in nasute or snout soldiers; mandibles small, normal, or extremely large and variable in mandibulate soldiers; compound eyes absent, vestigial, or large; ocelli absent or two when present; antennæ moniliform, short or long, many-segmented; prothorax free, smaller than head; legs short and stout, with four- or five-segmented tarsi and two claws; apterous, brachypterous, or macropterous; wings two pairs, similar in size, shape, and venation; venation simple with few cross veins, but some with intricate network, folded flat, and with basal fractures to permit shedding; cerci present, short and simple, or two- to eight-segmented.

The members of this order are among the most highly specialized, interesting, and destructive of insects. Allowed their rightful place in nature they devote their energies to the construction of burrows in wood and in the soil, the building of huge mounds, the culture of fungi for food, and the consumption and reduction of dead vegetable matter. Wherever certain species come in contact with civilized man they destroy portions of wooden buildings, fences, and other possessions made from plant sources and are thus responsible for large financial losses in the tropical and the warmer temperate regions. Their nests or termitaria may be constructed wholly underground or entirely or partly above the surface and vary greatly in architecture. Aërial nests are relatively small and are attached to dead trees, stumps, and other sources of food or are excavated in dry wood. Termite mounds (Fig. 63) in the scrublands of tropical Africa and Australia vary from one to twenty feet in height and are made by cementing together bits of earth, wood, and excrement with saliva. The interiors are honey-combed with chambers and galleries in which fungi are cultivated for food.

Among the lower orders of insects they are most remarkable because of their social habits and the highly developed caste system which somewhat resembles those of ants, bees, and wasps.

¹ The termites were long placed in the order NEUROPTERA as a group, tribe, or family. Brullé (1832) separated them into a separate order ISOPTERES, but it was not until 1895 that Comstock and Comstock used the correct name ISOPTERA which has been generally accepted by entomologists the world over.

The author is indebted to S. F. Light for reading this chapter and for making many important suggestions and corrections.

IMPORTANT ANATOMICAL CHARACTERS

External	Internal
<p>Size — small, medium to large.</p> <p>Shape — usually elongated, flattened; queens may be very greatly enlarged (2-3 in. long and $\frac{1}{2}$ in. in diameter).</p> <p>Exoskeleton — thin and tender or tough and elastic; portions sclerotized and chitinated; smooth or hairy.</p> <p>Color — white, pale yellow, amber, reddish, brown, or black.</p> <p>Head — prognathous or rarely hypognathous; free, small and circular, oval or elongated and greatly developed in some soldiers; mandibulate (with prominent mandibles) or nasute (with snout and vestigial mandibles); usually heavily sclerotized or chitinated.</p> <p>Compound Eyes — well developed and faceted, reduced, vestigial, or absent. Usually present in macropterous and brachypterous forms and absent in apterous forms.</p> <p>Ocelli — absent or two present: only in combination with compound eyes in winged individuals.</p> <p>Antennae — short or long, moniliform, nine- to 30-segmented.</p> <p>Mouth Parts — typically orthopteroid in form; mandibulate or nasute.</p> <p>Clypeus — narrow; labrum — well developed, variable in shape; mandibles — toothed, strong, asymmetrical, and often greatly enlarged and curiously formed in mandibulate soldiers; rudimentary or vestigial in nasute soldiers; maxillae — well developed; galea — two-segmented and hood-like; lacinia — strongly chitinated and apically toothed; maxillary palpi — five-segmented; labium — with large submentum, separate glossae and paraglossae, four-lobed; ligula, three-segmented palpi; hypopharynx large.</p> <p>Thorax — reduced in worker and often in the soldier castes, and large in more primitive forms; segmented. Prothorax — free, usually narrower than head, flattened dorsally, variable in form, and of taxonomic value in separating species; meso- and metathorax — wider than long, sternites small.</p> <p>Legs — short and stout; tarsi — four- to</p>	<p>Digestive System.</p> <p>Alimentary Canal — mouth opens into the narrow tubular <i>pharynx</i> which joins the <i>oesophagus</i> — a straight tube connecting with crop in posterior part of thorax; <i>crop</i> — sac-like, thick walled; <i>gizzard</i> — ring-like or pronounced; armed with teeth or denticles; <i>fore intestine</i> — tubular; <i>oesophageal</i> valve constitutes posterior portion; <i>mid-intestine</i> — tubular stomach which may encircle hind intestine; four <i>enteric caeca</i> arise from anterior portion and two to eight <i>Malpighian tubules</i> from the posterior areas of the stomach; <i>hind intestine</i> of <i>Zootermopsis nevadensis</i> (Hagen), according to Child (in Kofoid <i>et al.</i>; 1934, p. 63), is divided into six regions: (1) <i>proventriculus</i> or small intestine; (2) <i>vestibule</i>; (3) <i>large intestine</i>; (4) <i>intestinal caecum</i>; (5) <i>short colon</i>; and (6) <i>rectum</i>.</p> <p>Salivary Glands — prominent, open at base of hypopharynx.</p> <p>Circulatory System. Normal; eight- to 10-chambered heart continued into a prolonged aorta.</p> <p>Respiratory System. Two pairs thoracic spiracles; six to eight pairs abdominal spiracles.</p> <p>Nervous System. Normal with different degrees of development of the two large head ganglia; three thoracic and six abdominal ganglia.</p> <p>Reproductive System. Sexual organs functional in reproductive caste, aborted or functionless in soldier and worker castes.</p> <p>Male — testes simple, eight to 10 lobes in or near abdominal segment VIII; <i>vasa deferentia</i> — pair of short tubes uniting to form the <i>vesiculæ seminales</i> and <i>ejaculatory duct</i>.</p> <p>Female — queen enormously developed sexually and capable of producing a tremendous number of eggs; normally with 30 to 45 panoistic ovarioles opening separately into the two oviducts, which unite by a common tube into a genital pouch that receives contents</p>

IMPORTANT ANATOMICAL CHARACTERS—*Continued*

<i>External</i>	<i>Internal</i>
<p>five-segmented (typically four-segmented but indistinctly five-segmented in genera like <i>Termopsis</i>, <i>Zootermopsis</i>, <i>Hodotermopsis</i>, <i>Archotermopsis</i>, and related forms, and distinctly five-segmented in <i>Mastotermes</i>); in alates of members of the family KALOTERMITIDÆ an <i>empodium</i> is present; basal segments of tarsi very small; pair of curved <i>claws</i> present.</p> <p><i>Wings</i> — absent or two pairs, longer than body, slender, thin, membranous; similar in size, shape, and venation or dissimilar in primitive forms; veins few and strong in subcostal and anal areas, forming an intricate and delicate network in remaining areas; basal or humeral suture on both pairs, or on fore wings only, permitting shedding of wings by rearing the abdomen; * large anal lobe in <i>Mastotermes</i>.</p> <p><i>Spiracles</i> — two pairs.</p> <p><i>Abdomen</i> — 10-segmented, soft or partly chitinized in plates; sternite 1 reduced.</p> <p><i>Spiracles</i> — ordinarily eight pairs on the first eight segments; six pairs in queens.</p> <p><i>Cerci</i> — present, hairy, short, simple or two- to eight-segmented.</p> <p><i>Genitalia</i> — rudimentary or not evident.</p> <p><i>Male</i> — ninth sternite sometimes divided.</p> <p><i>Female</i> — seventh sternite enlarged to form subgenital plate. Hidden ovipositor present in <i>Mastotermes</i>. <i>Styli</i> — pair of very small ones may be present on sternite 9 in both sexes or in either and in soldiers and workers.</p>	<p>of spermatheca and colleterial glands in abdominal segment VII.</p> <p>Frontal Gland. A somewhat spherical gland arising in the abdomen or thorax, connected with the brain, and opening at the <i>fontanel</i> or <i>dorsal pore</i> of most forms or the rostrum of the nasute soldiers; peculiar to termites and common in the soldier caste. Secretion defensive in some cases and uses unknown in others. Thompson (1916) believes the fontanel arose from the original missing median ocellus which it replaces.</p>

* Zorapterans also shed the wings. Certain soil-burrowing cockroaches, *Panesthia* of Australia, bite off their wings. Females of the fig wasp, *Blastophaga*, often tear off the wings in squeezing through the small eye of the fig.

CASTES

I. **Reproductives.** — Sexual males and females responsible for the maintenance of old colonies and the establishment of new ones.

The founders and oldest residents of a colony, community, or termitarium usually consist of the royal pair, the king and queen; dealated sexuales

which are the parents of all the members living therein. The males may be extremely small whereas the queens may become exceedingly large, elongated, fat, worm-like creatures $3\frac{1}{2}$ in. or more long, whose only aim in life is to be fed and to produce countless thousands of eggs. Such female individuals have been thought to live from 6 to 15 years and to lay as many as a million eggs during their life span. They are said to be the most prolific of all insects.

1. **Macropterous or Winged Forms.**

Bodies chitinized and pigmented yellow, brown, or black; two pairs of fully developed wings longer than the body; compound eyes large and widely separated; paired ocelli usually present. Deälated forms may be the royal pair, but great numbers of these winged sexuales appear every year and swarm from the original colony to disperse, pair, mate, and establish new colonies. Swarming may occur during the day or night and frequently follows rain in the fall and spring months. The aërial experience is of short duration and is most hazardous since great numbers of the swarming insects are devoured by all sorts of birds, insects, and other animals. Only a relatively small percentage, but sufficient to perpetuate the species, actually survives to establish new colonies. In Mt. Lassen National Park, just before sunset on May 1, 1923, I witnessed a sudden explosion-like emergence of thousands of winged reproductives of *Zootermopsis nevadensis* (Hagen) from a large yellow pine stump. The impetuous individuals literally stampeded from the exit holes as if in a frantic effort to try their wings. They continued to swarm out for about 15 minutes, and the immediate woods were full of these reckless fliers. During an hour of careful observations no predators of any sort were in evidence. In the Yosemite Valley in early June I removed 50 deälated pairs of the same species which were constructing new cells in the sapwood under the bark of a small yellow pine log $1\frac{1}{2}$ ft. in diameter and 12 ft. in length.

2. **Brachypterous or Short-Winged Forms.**

So-called supplementary reproductives. They are most common among the subterranean forms and may develop in from 6 to 8 weeks. Wings are short or vestigial and scale-like and with venation visible but are without the characteristic basal fracture. They are pale yellow, grayish, or whitish with small compound eyes and ocelli present or absent. They remain hidden during their existence and may supplement or even exceed the queen in the production of fertile eggs.

3. **Apterous or Wingless Forms.**

These are wholly wingless individuals which are comparatively rare among supplementaries and occur only among the more primitive species. They are without pigmentation, the compound eyes are vestigial, and ocelli are absent. They are similar in appearance to members of the worker castes.

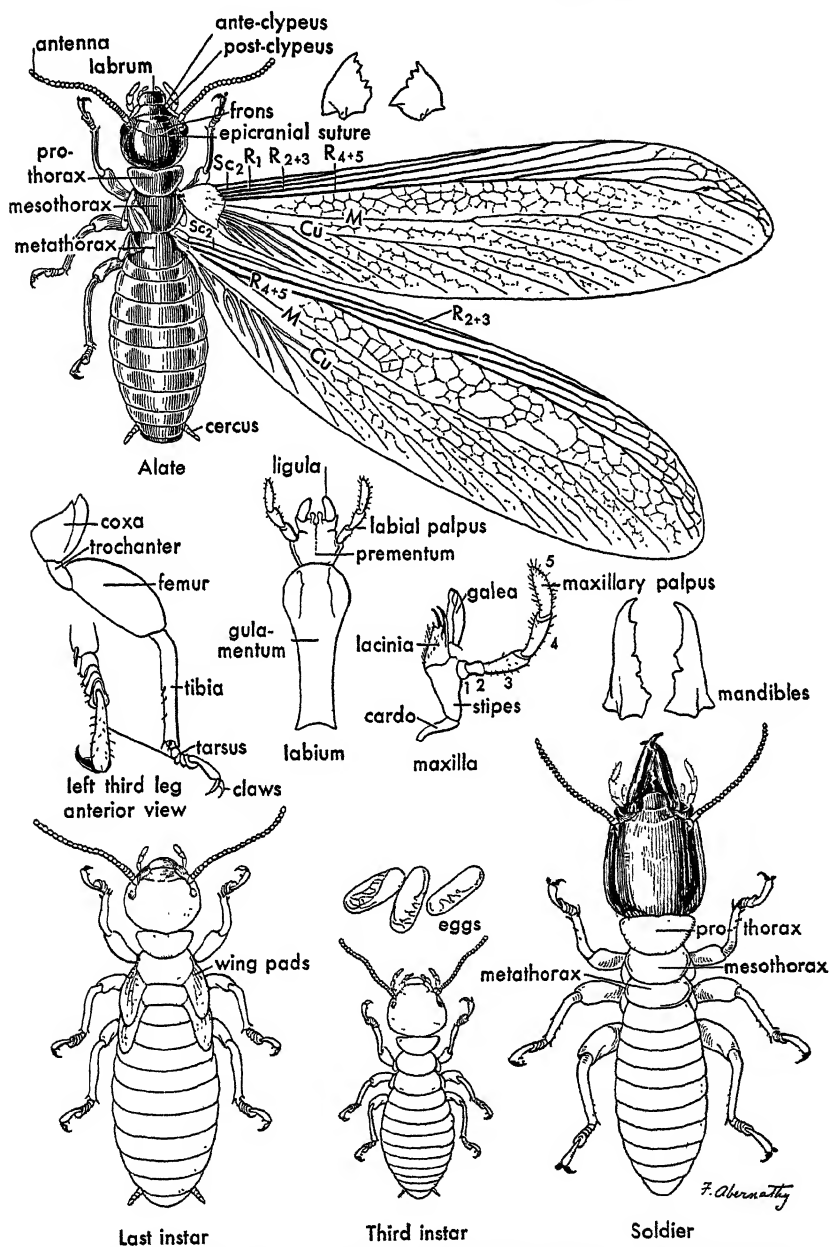


FIG. 62. The large termite, *Zootermopsis angusticollis* (Hagen). Drawing showing life history and important anatomical characters.

II. Sterile, Aborted, or Sexually Arrested Forms.

4. Workers.

Soft, pale-colored, wholly apterous individuals, usually without eyes except in those species that forage above ground, in which case rather well-developed, reduced, or vestigial compound eyes may be present. The mouth parts are adapted to reduction of various types of hard and soft vegetable materials. They show little specific differentiation and are difficult to classify. They are occasionally dimorphic, rarely trimorphic, and constitute small, intermediate, and large sizes in the higher genera, *Termes*, *Odontotermes*, and *Nasutitermes*. Workers perform all of the duties of the colonies except reproduction, defense, and dispersion. They construct the termitaria, galleries, covered passages, and fungus gardens, collect and provide the food, feed the queen, soldiers, and young, care for the eggs, and, in species without soldiers, they also defend the colonies against marauders.

Workers do not appear in all genera of termites. In *Zootermopsis* and *Archotermopsis* the nymphs perform the work.

5. Soldiers.

The members of this caste are of either sex and may or may not have compound eyes. Faceted eyes occur in *Hodotermes*, vestigial ocelli may sometimes be present, and the antennæ have fewer segments than in the reproductives. There may be large, intermediate, and small individuals. The soldiers are highly specialized in development of the head and the mandibles and accordingly may be divided into two types:

- (1) *Mandibulate* — in which the head is very greatly enlarged and heavily chitinized, and the mandibles greatly developed into variously shaped effective or, in some cases, seemingly useless weapons of defense. So prominent are these in many species that the soldiers are unable to procure their own food, and must be fed by the workers. They are the protectors of the colony who either plug up the burrows or runways with their enlarged heads or guard the entrances with snapping mandibles.
- (2) *Nasute* — in which the head is prolonged into a snout and used to smear a sticky secretion upon their enemies in warfare. These individuals are, as a rule, smaller than those of the mandibulate type, and have vestigial mandibles and well-developed palpi.

The life history of termites is exceedingly complicated, and there are still disagreements as to the cause of the origin of castes. The eggs are pale, smooth, oval, or elongated, and the young all appear very much alike. The food is prepared either by the queen, the workers, or the immature reproductives. It consists of saliva, various forms of dead or living vegetable substances, and fungi as well as proctodæal matter, the cast skins, and the dead of the colony. Licking and grooming each other is a characteristic of termites. Breeding continues throughout the year, and individual queens may live from several to many

years. Colonies are normally quite small but may become exceedingly large and continue as termite cities for many years. No one has yet determined the ages of the individuals of the colonies, so no definite statistics can be given on this point.

Termites are also classified according to their habits as (1) subterranean and (2) wood-dwelling.

- (1) **Subterranean** forms are those that either nest below the surface of the soil or, if extending their termitaria above the ground, require an underground connection by means of mounds, burrows in wood, or coverways up the exterior surfaces of trees, posts, or buildings. Many of these feed upon living or dead vegetable materials such as wood, leaves, fungi, and debris, and others are called fungus termites from their habit of cultivating certain fungi for food purposes.

The best developed castes are found among the fungus termites, and the royal pair is usually enclosed in a thick-walled clay cell near the middle of the termitarium. The termitaria may be entirely subterranean or may extend to the surface or rise some distance above it, in which case it is formed of thick, hard, earthen walls. Such termitaria may vary from a few feet in height and diameter to great pillars or mounds 15 to 30 ft. high and sometimes almost as much in diameter. The occupants often build coverways up the trunks of trees. The fungus gardens are distributed throughout the mound in a somewhat irregular fashion. Other termitaria may be constructed wholly beneath the surface of the soil. The inhabitants of these are usually smaller species, and little or no visible evidence of their habitations is seen above ground. Some subterranean species erect cylindrical or tapering chimneys or ventilators above the surface of the soil. Carton nests on or above the ground are also constructed by some genera.

A few subterranean species forage above ground in the open, cutting grasses and moving in great numbers over considerable areas. Such species may be very destructive to living vegetation, to wooden fences and structures, and to plant products of all kinds.

Other species may nest in the walls of the large nests or in nests made in trees, or under stones, logs, and other suitable hidden places.

- (2) **Wood-dwelling** forms are species that require no subterranean connections but are able to live in wooden structures, fences, poles, stumps, and trees in or on which the nests or termitaria are galleries eaten out of the wood. They are often responsible for great damage to wooden structures and products made from plant materials but always work under cover.

In the main, termites are considered to be very destructive insects in so far as man is concerned because of their ravages in search of food. They not only destroy grasses and living trees and weaken and often ruin fences, poles, furniture, and wooden structures of all kinds, but also devour books, cartons, linoleum, and almost every conceivable product of plant origin.

On the other hand, termites perform a very great service in nature by the effective reduction of dead wood and other vegetable products, which they

convert into food, excrement, and perhaps also fertilizers for the continued production of other plants. The excrement or pellets are often of a characteristic

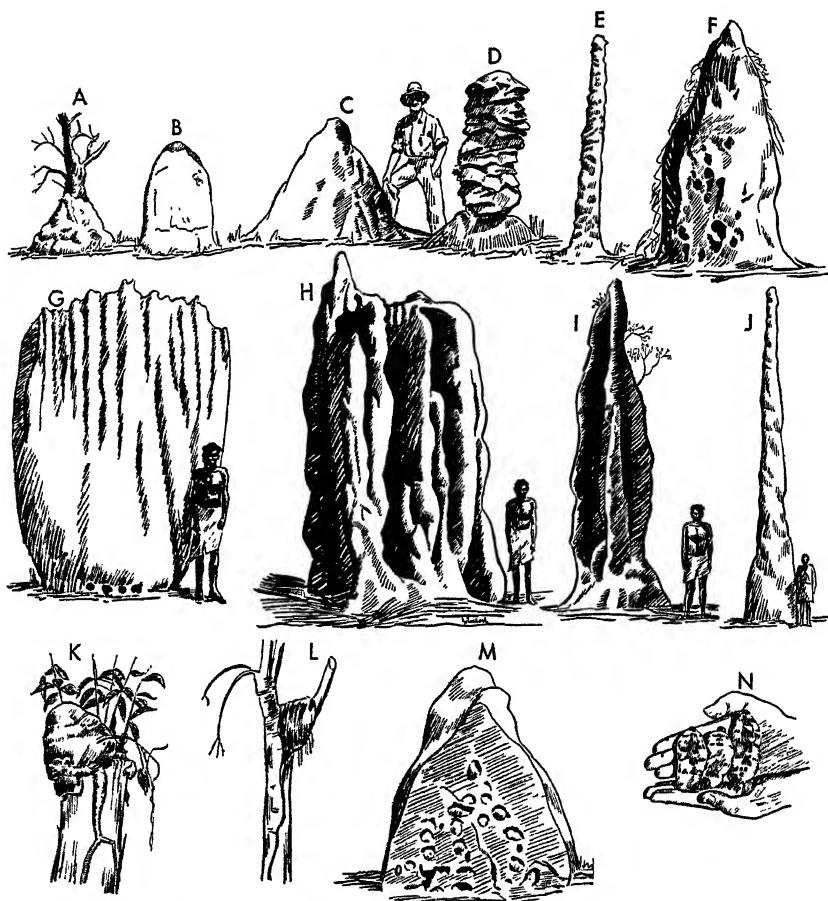


FIG. 63. Termite mounds or termitaria. A, B, C, D, J, from South Africa; D, *Nasutitermes lamarianus* (Sjöstedt), Belgian Congo; E, vent of subterranean nest, South Africa; F and M, exterior and cross-section of mounds of *Termes redemani* (Wasmann), Ceylon (F, after Bugnion; M, from Escherich); G, *Amilermes meridionalis* (Froggatt), Australia (after Froggatt); H, *Nasutitermes triodia* (Froggatt), Australia (after Hill); I, *Nasutitermes pyriformis* (Froggatt), Australia (after Froggatt); K and L, niggerhead nests of *Nasutitermes corniger* (Motschulsky), Panama (after Snyder); N, queens of *Macrotermes bellicosus* (Smeathman), Nigeria (drawn from Schechter).

shape for a species and may be present in the burrows in great quantities. These not only assist in identifying the work as that of termites but may make it possible to name the genus and even the species responsible.

FOSSIL RECORD

It is generally supposed that termites arose in Eocene times, but the earliest known fossils occur in the Lower Tertiary (Snyder, 1925). To date three families (Schröder, 1925) are represented as follows:

In the family MASTOTERMITIDÆ Silvestri, fossils of *Mastotermes* Froggatt have been taken in the Upper Eocene of Bournemouth and at Gurnet, Isle of Wight, England; in the Upper Oligocene of Schossnitz, Silesia, Czechoslovakia; in the Miocene of Radoboj, Croatia, Yugoslavia; and in Tennessee (Light). Living forms of this genus, *M. darwiniensis* Froggatt, occur in northern tropical Australia. The genus *Miotermes* Rosen has been taken from the Miocene of Florissant, Colo.; the Lower Miocene of Radoboj; and the Upper Miocene of Oeningen and of Randeck, Germany.

The family KALOTERMITIDÆ Banks is represented by seven species in Baltic Amber; two species in the Upper Oligocene of Rott, Germany; four species in the Miocene of Florissant, Colo.; two species in the Upper Miocene of Oeningen, Germany; one species in Upper Miocene of Gabbro, Italy; and seven species in Copal deposits. Among the genera thus represented are: *Archotermopsis* Rosen, *Xestotermopsis* Rosen, *Parotermes* Scudder, *Hodotermes* Hagen, and *Kalotermes* Hagen.

Many species of the family TERMITIDÆ (Westwood) Light have been taken, especially in Baltic Amber and Copal, in Europe, and in other deposits as listed in the family KALOTERMITIDÆ. The genera *Leucotermes* Silvestri, *Eutermes* Fr. Müller, *Termes* (Linn.) Holmgren, *Odontotermes* Holmgr., (?) *Microtermes* Wasmann, and *Microcerotermes* Wasm. are represented.

The termites are typically tropical insects that have invaded the warmer temperate regions. It may be calculated that there are approximately 100 genera and 1,600 species distributed somewhat as follows by species: African 500, Indo-Malaysian-Papuan 450, Neotropical 350, Australasian 100, Palearctic 100, and Nearctic 100. In 1934 Light estimated there were about 130 genera and 1,500 species. In North America Light accounts for 55 species of which only two are supposedly introduced.

KEY TO FAMILIES

1. Tarsi five-segmented; hind wing with large anal lobe **MASTOTERMITIDÆ** p. 168
 Tarsi four-segmented; hind wing without anal lobe 2
2. Fontanel¹ absent in all castes; empodium present (except in *Protermes*) 3
 Fontanel present in all castes; empodium absent 4
3. Ocelli absent; pronotum not always broader than head in soldier
 HODOTERMITIDÆ p. 168
 Ocelli present; pronotum broader than head . . . **KALOTERMITIDÆ** p. 169
4. Scale or stump of fore wing large, distinctly larger than that of hind

¹ A shallow depression of the forehead in which is situated the opening of the frontal pore from which sticky fluid oozes or is ejected. Also spelled fontanelle.

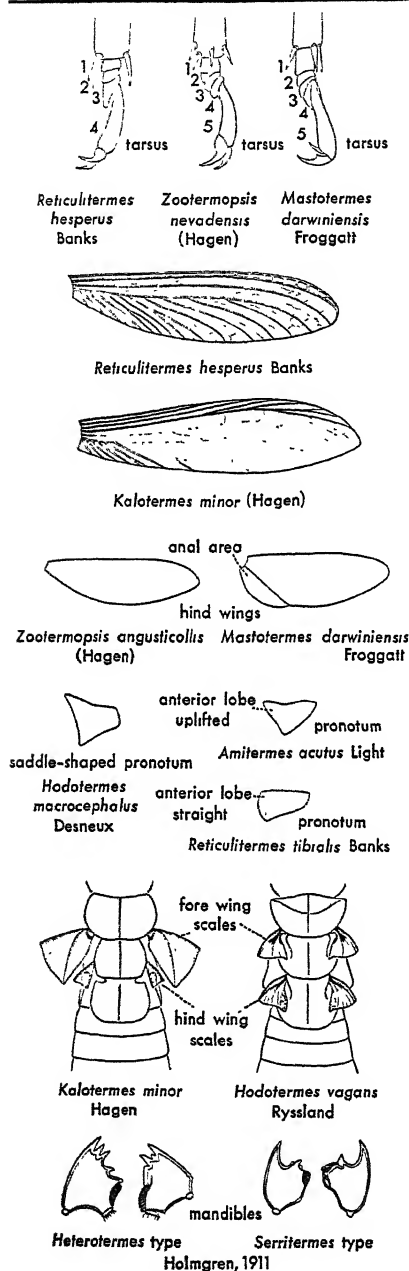


FIG. 64. Termites or ISOPTERA. Key panel.

wing; wing membrane often reticulated; worker with flat pronotum (except in *Rhinotermes*)

RHINOTERMITIDÆ p. 170

Scale of fore wing small; wing membrane never strongly reticulated; wings hairy; worker and soldier with a saddle-shaped pronotum

TERMITIDÆ p. 171

Family MASTOTERMITIDÆ Silvestri 1909 (Mas'to-ter-mit'i-dæ, from the Greek *μαστός*, the breast, + the Latin *termes*,¹ a woodworm or termite; referring to the broad thorax). Primitive Termites.

Sexes much alike and without enlarged queens; wings with complex net-like venation; basal fracture only on fore wings and an anal lobe on hind wings. Subterranean and wood-dwelling or dry-wood species which nest in small termitaria, usually underground, and feed upon the roots and trunks of living trees. They are often quite destructive to woodwork and wooden structures.

The family is represented by fossil forms in Europe and North America, and by a single species, *Mastotermes darwiniensis* Froggatt, living in tropical Australia, where it is often a serious pest.

Family HODOTERMITIDÆ Sjöstedt 1925 (Ho'do-ter-mit'i-dæ, from the Greek *ὁδός*, a pathway or road, + *termes*; referring to the paths made in gathering grasses for food).

A family of large termites having a worker caste and including but a

¹ Perrier (1934, footnotes 3, p. 74, and 1, p. 77) gives the derivation of *termes* from the

single genus, *Hodotermes* Hagen, and 15 species living in Africa and Central Asia. They are subterranean grass feeders.

Family KALOTERMITIDÆ¹ Banks 1920 (CALOTERMITIDÆ Enderlein 1909) (Ka'lo-ter-mit'i-dæ, from the Greek *καλός*, beauty, + *termes*; beautiful termites).

Primitive dry and damp wood species living in and feeding upon dry, damp, or wet wood below or above ground and not requiring a ground connection. They are small or relatively large species that lack the clypeal median line and fontanel but with the gula longer than broad and ocelli usually present. The worker caste is lacking, the nymphs performing the duties of the colony.

According to Light (1934), the family is represented by about 20 genera and 240 species, many of which are destructive to wood and various products derived from it. Intestinal protozoans are associated with these wood-destroying forms.

Kalotermes Hagen, the dominant genus, is represented in North America by four important species: *K. snyderi* Light extends from Mexico through the Gulf States northwards along the Atlantic coast; *K. hubbardi* Banks inhabits the arid southwest of the United States and western Mexico; *K. minor* Hagen occupies the western Pacific region. All these may be destructive to wooden structures, dead timber, and wood products of all kinds, while *K. castaneus* (Burmeister) (*Neotermes*), of Florida and the West Indies, attacks the roots, trunks, and limbs of living citrus, oak, mangrove, and other trees. In Ceylon *K. dilatatus* Bugnion and Popoff, *K. greeni* Desneux, and *K. militaris* Desneux attack the roots of growing plants and are injurious in tea plantations.

Members of the genus *Zootermopsis* Emerson are among the largest termites and live in damp wood below or above the surface of the soil. They often swarm at sunset in great numbers from stumps, fallen logs, and partly killed and dead standing trees, but are rarely of economic importance. The three American species all occur west of the Rocky Mountains: *Z. angusticollis* (Hagen) along the Pacific coast; *Z. nevadensis* (Hagen) in the foothills and mountains west of the Rockies; and *Z. laticeps* (Banks) in the mountains of Arizona and New Mexico.

Cryptotermes brevis (Walker), occurring in Florida, West Indies, Mexico, Central America, and southward to Brazil, is probably the most destructive dry-wood termite in that area. *C. piceatus* (Snyder) is a dry-wood species infesting wooden structures, boxes, furniture, and similar articles. It occurs throughout the tropical Pacific area.

Greek *ρέπυα*, an end, death; referring to the insect known as the death watch, which in olden times was thought to be the wood louse, *Atropos*, but was really the beetle, *Anobium*. Its ticks foretold approaching death (see the death watch, p. 576).

¹ The genus from which this family name is derived was originally spelled *Kalotermes* by Hagen (1853). Subsequently he changed it to *Calotermes* (Hagen 1858, p. 33) from which Enderlein (1909) erected the family CALOTERMITIDÆ. Both these names have been applied in recent years. The confusion has arisen from the transliteration of the Greek letter *κ* into the English letter K or C. There seems to be no uniform practice in this respect, either one being commonly used in biological names.

"Since evidence of the derivation of the word is not contained in the original publication the original spelling (*Kalotermes*) should be preserved." (*Int. Rules of Zool. Nom.*, Opinion 34.)

Family RHINOTERMITIDÆ Light 1921 (Rhi'no-ter-mit'i-dæ, from the Greek *ῥίς*, *ῥινός*, nose, + *termes*; referring to the deeply grooved and greatly extended labrum of the nasute or rostrate soldier).

Mostly small, subterranean species (except for the damp-wood members of the genus *Protrhinotermes*) which have the fontanel present; large fore-wing

scale; reticulated, hairless wings; and flat pronotum in the worker caste. They are among the most destructive species and according to Light (1934) are "responsible for a great part of the termite damage of the world." The family is composed of 12 genera and 140 species occurring in the tropics and warmer temperate regions. The genus *Reticulitermes* Holmgren is one of the most important in the order. In America, Light lists 10 species which extend their range throughout the entire United States (Emerson, 1937). *R. flavipes* Kollar has the widest distribution in the east and southwest, with *R. hageni* Banks and *R. virginicus* Banks occupying about half of that territory. *R. tibialis* Banks appears to have spread over the widest area in the central and south-central portions. *R. hesperus* Banks occurs chiefly along the Pacific slope from British Columbia into Lower California.

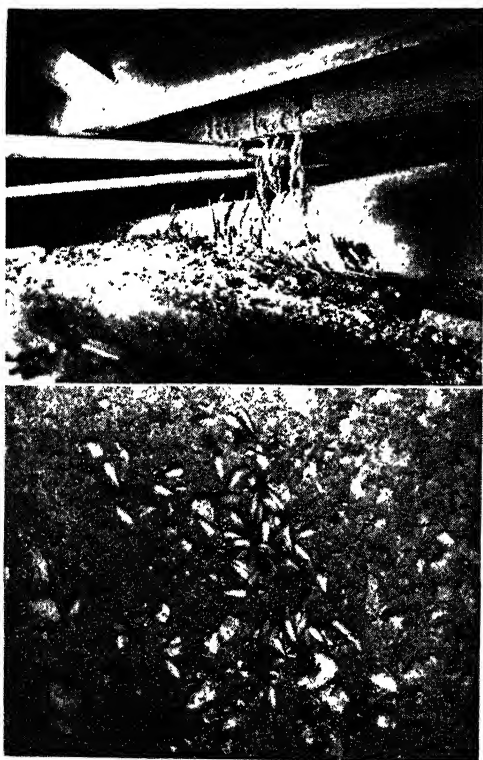


FIG. 65. The Western subterranean termite, *Reticulitermes hesperus* Banks. Top, coverways under a wooden house; bottom, a colony swarming from the ground following a rain in the autumn. (Courtesy Alpine Wood and Supply Co., 1933.)

In the tropics and warmer temperate regions the members of the genus *Coptotermes* Wasmann are especially important because of their destructiveness. All are subterranean. The soldiers are provided with large curved mandibles as well as a fontanel for the discharge of fluids. *C. formosanus* (Shiraki) lives in large carton nests always in contact with wood. It is a very destructive species common to South China, Formosa, Southern Japan, and the Hawaiian Islands. The milk-white termite, *C. lacteus* (Froggatt), is a common and de-

structive Australian species which constructs large dome-like termitaria up to 6 ft. high. The common name comes from the white discharge of the fontanel of the soldiers.

Heterotermes tenuis (Hagen) is one of the species most injurious to wooden structures in the West Indies, Mexico, Central America, and northern South America. *H. aureus* Snyder occurs in California, Arizona, and Mexico and is very destructive in the last two regions.

Family TERMITIDÆ¹ (Westwood 1840) Light 1921 (Ter-mit-i-dæ, from the Latin *termes*, a woodworm or termite).

A large family of tropical and subterranean species in which most of the soldiers have the head extended into a rostrum from which the fluid secretion may be extruded in tenacious threads to repel and entangle enemies. The anterior wing scale is small, the wings are partly reticulated, and the membrane and margins are somewhat hairy. The fontanel is present, and the pronotum of the soldier is saddle-like in shape. These species lack the protozoan fauna in the digestive tract. This is the dominant family of the order and has some 100 genera and 1,200 species.

In the genus *Amitermes* Silvestri the nasute soldiers have large sickle-shaped or hook-like and toothed mandibles.

The meridional or magnetic termite, *Amitermes meridionalis* (Froggatt), in Australia, erects narrow, earthen, wall-like or wedge-shaped mounds from 3 to 12 ft. high and almost as long, with the narrow ends facing north and south and the sides east and west.

The genus *Nasutitermes* Banks (*Eutermes* Heer) is a large and important one. *Nasutitermes exitiosus* (Hill), one of a number of mound-building species in Australia, erects pillar-like mounds up to 18 ft. in height. Concerning the occupants of a small mound 1½ ft. high and 4 ft. wide at the base, the following interesting facts have been assembled:²

Total population	1,800,000
Workers	1,560,000
Soldiers	200,000
Nymphs	40,000
Humidity exceeded	95%
Temperature relatively high	

Nasutitermes costalis Holmgren is common and abundant in the West Indies, Mexico, Central America, and northern South America. It builds nigger-head nests on the trunks and larger branches of trees and on posts and poles and sometimes injures sugar cane. The nasute soldiers have very pointed heads and the alates fly by day.

¹ See footnote 1, page 168.

² Report of the Council of Science and Industrial Research of Australia, Vol. 9, 1938.

Termes horni Wasmann of Ceylon is injurious to growing Job's tears, a grass allied to maize.

Nasutitermes ripperti (Rambur) of Jamaica builds aerial nests and feeds on the roots of various plants including sugar cane.

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CHAPTER XVII

14. Order ZORAPTERA¹ Silvestri 1913

(Zor-ap'te-ra, from the Greek ζωρός, pure, + ἄπτερα, wingless; because the first species described were wingless.) German, Bodenläuse.

Zorapterans.

Minute apterous and winged insects with biting mouth parts; simple metamorphosis; nine-segmented, moniliform antennæ; two-segmented tarsi; eyes absent in apterous forms, compound eyes and ocelli present in winged forms; wings long and slender, fore pair much larger than hind pair, with few branching veins, capable of being shed; cerci short, unsegmented.

These very small insects are scarcely more than 3 mm. long and have a wing expanse of only 7 mm. They are pale in color and look a great deal like miniature termites. This resemblance is further emphasized by their ability to cast off their wings, by the bead-like antennæ, by their habit of living in colonies under bark and in dead wood and in the soil, and by their frequent association with termites. The head is quite large and free. The apterous forms are totally blind, whereas the winged individuals have well-developed compound eyes and three oval ocelli. The mandibles are stout; the maxillary palpi five-segmented; the labium has a completely divided prementum and three-segmented palpi; the prothorax is free and nearly circular in form; legs similar, hind femora short and stout, first tarsal segment very short; wings varying considerably in size but of the same membranous texture, long and narrow, with few veins, deciduous, leaving stubs attached to the thorax; abdomen 10-segmented; cerci short, unsegmented, with wide bases and few or many long hairs. There are two thoracic and eight abdominal spiracles. The crop is wide, the stomach ovoid; hind intestine convoluted; about six Malpighian tubules; three thoracic and but two abdominal ganglia.

The order is a very small one and has but a single family, ZOROTYPIDÆ Silvestri 1913, a single genus, *Zorotypus* Silvestri, and some 12 species. The first specimens, all wingless, were collected in West Africa and described as *Zorotypus guineensis* by Silvestri in 1913. Since then other species have been taken in North America, South America, Java, Sumatra, Ceylon, and Hawaii. The two species occurring in this country are *Z. hubbardi* Caudell, in Florida and Texas, and *Z. snyderi* Caudell in Florida. The order, as now known, appears to be tropical or semitropical in distribution.

¹ These insects have also been arranged in ZORAPTERA as a suborder of the CORRODENTIA. Crampton erected the order PANISOPTERA for them in 1919.

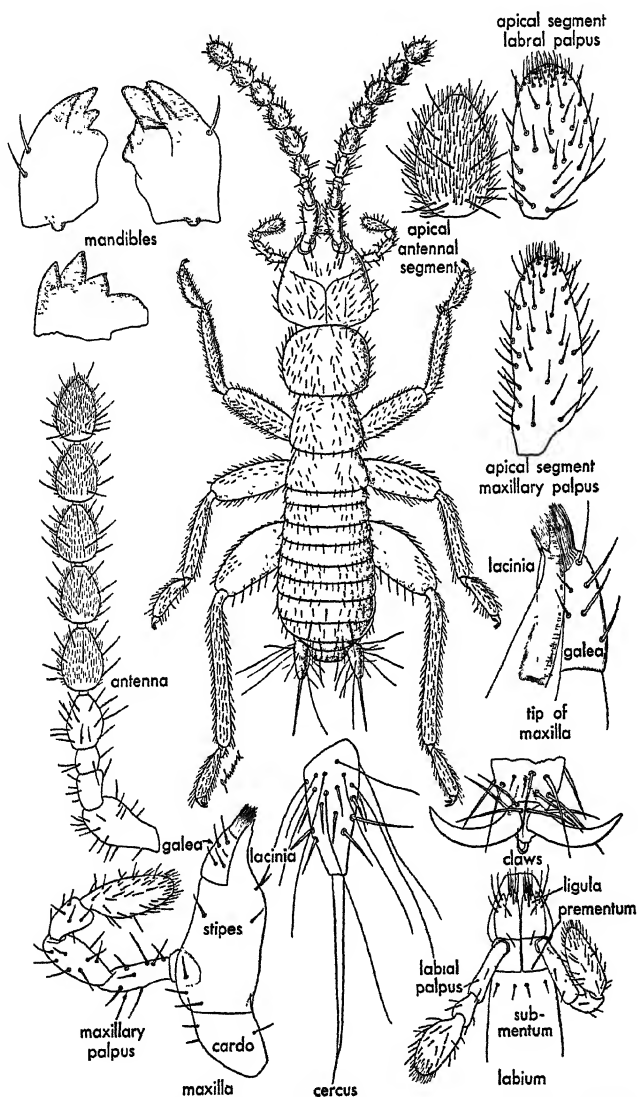


FIG. 66. *Zorotypus guineensis* Silvestri and important characters. (After Silvestri, 1913.)

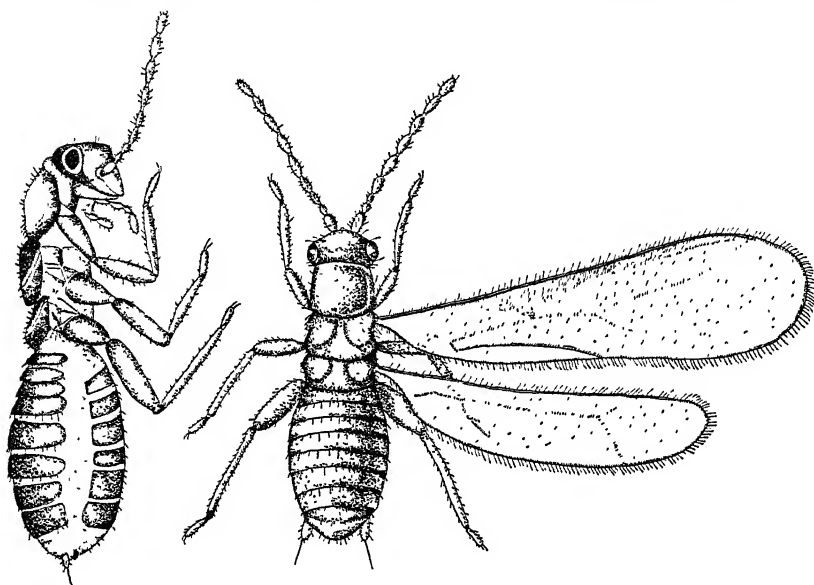


FIG. 67. Dealated and winged females of *Zorotypus hubbardi* Caudell. (Redrawn from Caudell, 1920.)

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CHAPTER XVIII

15. Order EMBIOPTERA¹ Shipley 1904

(Em'bi-op'ter-a, from the Greek *ἐμβιος*, lively, + *πτερά*, wings.) German, Embien. French, Embiides.

Embiids, Embiopterans, Webspinners.

Small, slender, campodeiform insects with biting and chewing mouth parts and simple or hemimetabolous metamorphosis. Head large, antennæ filiform; compound eyes small in female, often large in male; ocelli absent; thorax nearly as long as abdomen; legs short and stout for running, tarsi three-segmented, first tarsal segment of forelegs enlarged to contain glands and spinnerets. Wings, two pairs, membranous, similar in size, shape, and venation, held flat over body in repose, present or absent in males, absent in females.

This is a small group of truly peculiar insects which is widely distributed throughout the tropical and more temperate regions of the world. Because of their secluded habits, embiids are scarcely known even to entomologists. Wherever the insects occur, their presence is indicated by the numerous filmy white webbed tunnels and coverways which they spin copiously throughout the range of their activities. Sometimes the webs are evident in the debris on the surface of the soil at the bases of grasses, weeds, and other plants during the rainy season, but more often they appear to occur under stones, bark, pieces of wood, dried dung, and similar objects which serve as covering and protection for their habitations. Some species, like *Clothoda urichi* (Sauss.) of Trinidad, live under the bark of trees and others are reported to inhabit by chance the nests of ants and termites. In California, where there is a distinct wet winter season and a dry summer season, colonies of *Gynembia tarsalia* Ross may be observed on open, grassy slopes and hillsides during the winter after the first soaking rains and until the vegetation dries up in early summer, when the species retreats into the soil. The members of this species are decidedly gregarious and may occur in large societies; and their silken coverways and tunnels extend over much of the surface of the ground and of whatever objects they are living beneath. Although much study and attention has been given to them over a period of many years, and large numbers have been confined in the

¹ The order name of these insects has been repeatedly changed. Among the important names used are: EMBIDINA Hagen 1861, EMBIDOPTERES Lamère 1900, EMBIIDINA Enderlein 1903, EMBIODEA Kusnezow 1903, EMBIOIDEA, EMBIARIA Handlirsch 1903, EMBIOPTERA Shipley 1904, ADENOPODA Verhoff 1904, OLIGONEURA Börner 1904, EMBIÆ Jacobson and Bianchi 1905, EMBIDOS Navás 1905, EMBIDARIA Handlirsch 1906, and ÆTIOPTERA Enderlein 1912. While the name EMBIIDINA appears to have priority, the author is using the generally accepted term EMBIOPTERA as recently employed by Imms 1930, Metcalf and Flint 1932, Folsom and Wardle 1934, Davis 1939, and Ross 1940.

laboratory at different times for closer observations, no males have been observed or collected. Ross has recently discovered that they reproduce parthenogenetically.

If the silken webbing is torn asunder, the insects appear to be little disturbed although they may feign death. But if personally molested, they react with lightning rapidity and dart forwards or backwards with equal agility. They offer no hostile resistance and avoid rather than court danger. Like termites, they shun light and apparently leave the tunnels and coverways only at night, yet they are active enough during the day if the sky is overcast and the temperature mild or if their abodes are molested. Those who have observed certain embiids state that the relatively large, somewhat cylindrical eggs, which have a prominent operculum at one pole, are laid in the tunnels in small groups uncovered or in a matrix of excrement and saliva and are covered with one or more layers of silk web. The eggs are more or less cared for by the parents, as in the case of termites and earwigs, but they are not transported about. Little is known of the life histories, including particularly the numbers of ecdyses and the life span. Spinning is acquired early and all forms including the first instar diligently ply the art of lining the extensive runways. It appears that both forelegs¹ are used and many threads are drawn simultaneously from the numerous spinning hairs on each of the enlarged tarsal segments so that the web is laid down with considerable rapidity.² Most species are very dark colored in the adult stage, some being almost black, and a few have a metallic luster. Others are often pale in color, and the members of our local apterous California species are pale tan or pinkish. Their food is thought to be wholly vegetable, and that chiefly dead and decayed. Perhaps fungi play an important part in the diet. Specimens have been confined in the laboratory for months with nothing but dead vegetable debris for food. At times they feed readily upon bits of fresh lettuce which they first enclose within their webs as they consume it.

The mouth parts are similar to those of the ORTHOPTERA, with all members well developed. The thorax is narrower than the head anteriorly and gradually widens posteriorly. In the apterous forms the segments are longer than wide but in the winged males they are wider. The legs are short and stout to enable them to travel freely in the small tunnels. The first segment of the fore tarsus is noticeably enlarged and bears the spinning organs. The middle pair of legs is somewhat reduced. The femora of the hind legs are greatly enlarged to accommodate the highly developed depressor muscles of the tibiae which probably motivate movement in reverse. The tarsi are three-segmented, but the middle segment is very small in the forelegs. Two or three sole bladders on the tarsal segments of the hind legs appear in some species and are of value in classification. Wings occur only in the males of

¹ The only other insects that use their fore tarsi for spinning silk are flies belonging to the family EMPIDIDÆ. See p. 776.

² There has been some controversy in past years regarding the exact location of the spinning organs since certain entomologists believed that the glossæ, or median ligular lobes of the labium, functioned as spinnerets (Enderlein, 1912, and Hagen, 1908, p. 223).

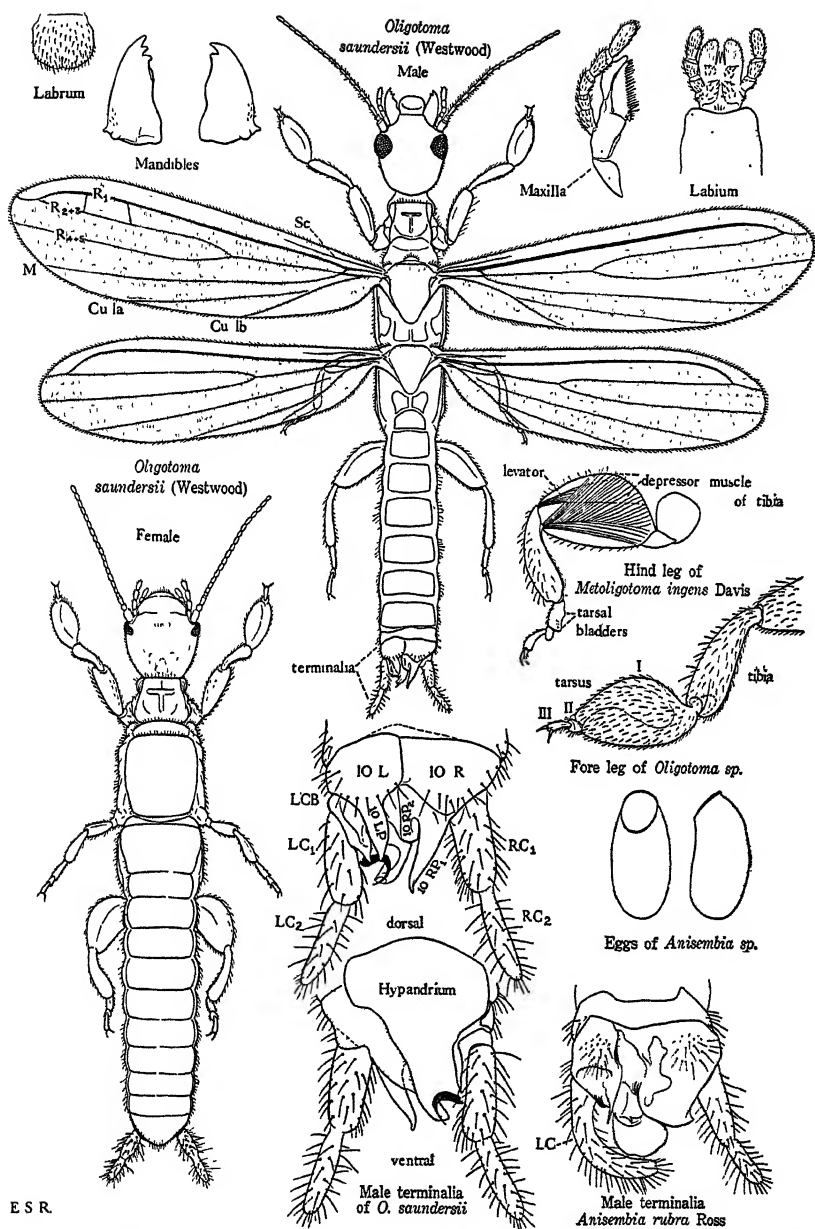


FIG. 68. EMBIOPTERA. Winged male and apterous female of *Oligotoma saundersii* (Westwood). 10 L, left hemitergite of abdominal segment X; 10 R, right hemitergite of same; 10 LP, process of left hemitergite; 10 RP, process of right hemitergite; LC₁, basal segment of left cercus; LC₂, terminal segment of same; LCB, left cercus basipodite; RC₁, basal segment of right cercus; RC₂, terminal segment of same. (Drawing by E. S. Ross.)

certain species and consist of two pairs which are rather fragile, dusky, membranous, and similar in size and shape. The venation is poorly developed, there being only a few longitudinal and cross veins which are slightly more pronounced in the fore pair. Hairs and transparent longitudinal lines between the veins and dusky areas are rather prominent features of these alar organs. Because of the nature of the wings the males must be feeble and erratic fliers. The abdomen is composed of 10 well-defined segments with evidence of an 11th segment. The cerci are usually two-segmented, but in the males of the genus *Anisembia* Krauss and *Metoligotoma* Davis one cercus, always the left member, is only one-segmented. There are two pairs of thoracic and eight pairs of abdominal spiracles.

Reproduction is sexual, but certain species are parthenogenetic. There may be one or many generations a year.

The internal organization is but poorly known. The alimentary canal is almost straight and consists of the mouth, buccal cavity, narrow pharynx, dilated cesophagus and crop, mid-intestine, and slightly coiled hind intestine with six rectal papillæ. The salivary glands are well developed and the Malpighian tubules vary from about 20 to 24. There are three thoracic and seven abdominal ganglia.

The palæontological record of the embiids is imperfectly known, owing no doubt to their fragility. The first members appear in the Tertiary Baltic Amber¹ and in the shales of the Lower Permian of Kansas,² Florissant, Colo., and in the Posttertiary of Africa and Asia. According to Tillyard (1926) some of these forms belong to a new order PROTEMBIARIA which may be an offshoot of the PROTORTHOPTERA.

This order of insects is now undergoing complete revision by C. Davis and Edward S. Ross, and it is impossible at this writing to include a satisfactory system of classification. According to Ross, who has kindly furnished most of the information as well as the splendid figures used in this chapter, the representatives are to be arranged in eight families, about 35 genera, and at least 135 species. The three families occurring in North America are ANISEMBIIDÆ Ross, OLIGEMBIIDÆ Davis, and the introduced OLIGOTOMIIDÆ Enderlein. The important world genera are *Anisembia* Krauss, seven species, North America; *Clothoda* Enderlein, five species, South America; *Dihybocercus* Enderlein, three species, Africa; *Embia* Latreille, 18 species, North Africa; *Embolyntha* Davis, five species, tropical America; *Haplëmbia* Verheeff, four species, Mediterranean region; *Metoligotoma* Davis, 21 species, Australia; *Oligëmbia* Davis, seven species, tropical America; *Oligotoma* Westwood, 23 species, Asia and Australia, and certain species now widely distributed by commerce; *Pararhagodochir* Davis, five species, South America; and *Rhagodochir* Enderlein, three species, Africa.

What appears to be one of the most widely distributed species is the date embiid, *Oligotoma nigra* Hagen, of the Mediterranean region which has been

¹ *Oligotoma antiqua* Pictet. = *Haplëmbia antiqua* (Pictet) (Davis, 1940).

² *Clothoda* spp.?

distributed with date offshoots into Texas, Arizona, and California, and probably elsewhere. According to Ross, other species introduced into North America are *O. humbertiana* (Saussure) into Mexico and *O. saundersii* (Westwood) into Florida, Texas, and Mexico. These two last-named species are the most widely distributed embiids throughout the subtropical and tropical regions of the world.

KEY TO FAMILIES

(By Consett Davis and E. S. Ross)

1. Tertiary or recent 2
Permian **PROTEMBIIDÆ**
2. Ventral structures in the male terminalia markedly asymmetrical . 3
Ventral structures in the male terminalia not markedly asymmetrical **CLOTHODIDÆ**
3. Fission of 10th abdominal tergite of adult male incomplete, hemitergites of this segment not separated by a membranous area extending forward to ninth abdominal tergite 4
Fission complete, hemitergites separated by a membranous area reaching ninth abdominal tergite 7
4. Wings with radial sector three-branched 6
Wings with radial sector two-branched 5
5. Left cercus of male smooth, without echinulations on inner side, always two-segmented, mandibles with apical dentations . **OLIGOTOMIDÆ** p. 182
Left cercus of male generally echinulate on inner side, often one-segmented; mandibles without apical dentations . certain **ANISEMBIIDÆ** p. 182
6. Wings with R_{2+3} bifid, R_{4+5} simple **TERATEMBIIDÆ** p. 182
Wings with R_{4+5} simple, R_{4+5} bifid **OLIGEMBIIDÆ** p. 182
7. Central and North American genera with R_{4+5} simple, or wingless, certain **ANISEMBIIDÆ** p. 182
Otherwise 8
8. Indo-Malaysian or Australian genera with the left cercus of the male one-segmented **NOTOLIGOTOMIDÆ** p. 182
Indian, African, Mediterranean, and Neotropical genera with the left cercus of the male two-segmented, the second segment being distinct **EMBIIDÆ** p. 182

SUBORDERS AND FAMILIES

(By C. Davis and E. S. Ross)

Suborder PROTEMBIOPTERA Tillyard

Family PROTEMBIIDÆ Tillyard

- Genus *Protembra* Tillyard Kansas Permian
" *Tillyardembia* Zalesky Russian Permian

Suborder EUEMBIOPTERA Tillyard

Family CLOTHODIDÆ Enderlein

- Genus *Clothoda* Enderlein South America, Florissant

Family EMBIIDÆ Burmeister

Genus <i>Embia</i> Latreille	Mediterranean to South Africa
“ <i>Parembia</i> Davis	Mesopotamia to India
“ <i>Metembia</i> Davis	“ “ “
“ <i>Pseudembia</i> Davis	“ “ “
“ <i>Dictyploca</i> Krauss	Africa
“ <i>Leptembia</i> Krauss	“
“ <i>Dinembia</i> Davis	“
“ <i>Berlandembia</i> Davis	“
“ <i>Donaconethis</i> Enderlein	“
“ <i>Dihybocercus</i> Enderlein	“
“ <i>Odontembia</i> Davis	“
“ <i>Enveja</i> Navás	“
“ <i>Rhagadochir</i> Enderlein	“
“ <i>Macrembia</i> Davis	“
“ <i>Chirembia</i> Davis	“
“ <i>Parachirembia</i> Davis	“
“ <i>Navasiella</i> Davis	“
“ <i>Calamoclostes</i> Enderlein	South America
“ <i>Pararhagadochir</i> Davis	“ “

Family OLIGOTOMIDÆ Enderlein

Genus <i>Oligotoma</i> Westwood	Africa, India, Orient, Papua, etc.
“ <i>Haplembia</i> Verhoeff	Mediterranean, Black Sea

Family OLIGEMBIIDÆ Davis

Genus <i>Oligembia</i> Davis	Tropical North and South America
“ <i>Diradius</i> Friederichs	South America

Family TERATEMBIIDÆ Krauss

Genus <i>Teratembia</i> Krauss	Argentina
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Family ANISEMBIIDÆ Ross

Genus <i>Saussurembia</i> Davis	Central America
“ <i>Mesembia</i> Ross	West Indies
“ <i>Anisembia</i> Krauss	North America, Antilles

Family NOTOLIGOTOMIDÆ Davis

Genus <i>Notoligotoma</i> Davis	Australia
“ <i>Metoligotoma</i> Davis	Eastern Australia
“ <i>Embonycha</i> Navás	Indo-China
“ <i>Burmilembia</i> Cockerell	Burmese Amber
“ <i>Ptilocerembia</i> Friederichs	Sumatra, Java

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CHAPTER XIX

16. Order CORRODENTIA¹ (Burmeister 1839) Comstock and Comstock 1895

(Cor'ro-den'ti-a, from the Latin *corrodens*, gnawing.) German, Flechtlinge. French, Psocides.

Psocids, Book Lice, Bark Lice, Dust Lice.

Minute to small, compact, apterous or alate, terrestrial insects with simple metamorphosis, modified biting mouth parts; head large and free; antennæ short or long and filiform; compound eyes usually large and widely separated; ocelli absent or three in number; prothorax small and neck-like; wholly apterous, brachypterous, or with two pairs of wings, hind pair much smaller than fore wings, venation simple; legs slender, femora sometimes enlarged, tarsi two- or three-segmented; cerci absent.

This somewhat neglected order is composed of curious but homogenous members which all look very much alike. Because of their small size, fragile bodies, and their general saprophagous habits, they have had few entomological admirers. A number of species have long been pestiferous and injurious in houses, granaries, mills, warehouses, libraries, and museums, where they live on cereal products, vegetable and animal debris, and on paste, glue, fungi, dead insects, beeswax, and other organic substances. There is hardly a building that does not harbor psocids, and they may literally swarm in mills, packing houses, and food warehouses. It is not uncommon to buy packages of prepared foods completely infested by these tiny, active creatures. They damage books² by eating away the paste and glue and often do considerable injury to botanical and zoological specimens. To dried insect collections they are often very destructive, and the entomologist must constantly be on the alert to protect his specimens from them.

¹ There has been a wide variance in the designation of this order of insects. Linnæus (1758), placed them in the NEUROPTERA. In 1839 Burmeister erected the order CORRODENTIA for the TERMITINA, EMBIDÆ, CONIOPTERYGIDÆ, and PSOCINA. Comstock and Comstock (1895) restricted the name CORRODENTIA to the psocids and that now seems proper, since all of the other groups included by Burmeister have been relegated to distinct new or to other existing orders. COPEOGNATHA was not erected by Enderlein until 1903 and PSOCOPTERA by Shipley until 1904.

² The most important insects injurious to books are termites, beetles, psocids, cockroaches, and the caterpillars of certain tineid moths. Of all these the beetles belonging to the family ANOBIIDÆ are the most important and include such economic species as *Catorama herbarium* Gorham of tropical Africa, *Dorcatoma bibliophagum* Magalhães of Peru, *Gastrallus laticollis* Pic of the Dutch East Indies, *Neogastrallus librinocens* Fisher of Florida, *Nicobium castaneum hirtum* Illiger of Spain, and *Silodrepa panicea* Linn. in many parts of the world. The last named species, commonly called the drugstore beetle is perhaps the most important destroyer of books. "Book-worm" is a very indefinite and vague term that might be used for almost any insect found in books, but there is no one specific species of that name.

ANATOMICAL CHARACTERS

External Anatomy	Internal Anatomy
<p>Size — minute to small, 1-7 mm. long.</p> <p>Shape — elongate and slender to robust.</p> <p>Integument — soft, smooth or hairy.</p> <p>Color — usually brownish but may be yellow, gray, black, or green.</p> <p>Head — large and mobile, hypognathous, with Y-shaped dorsal suture.</p> <p>Eyes — <i>compound</i> — usually large, but some composed of only seven or eight ommatidia.</p> <p>Ocelli — absent in apterous forms, three in winged forms.</p> <p>Antennæ — setiform or long and filiform, 13- to 50-segmented.</p> <p>Mouth parts — normal biting with modifications.</p> <p>Postclypeus — large; <i>anteclypeus</i> — small.</p> <p>Labrum — well developed.</p> <p>Mandibles — with basal molar area and toothed apices.</p> <p>Maxillæ — modified with two-segmented <i>galea</i>, reduced <i>stipes</i>, and four-segmented <i>palpi</i>.</p> <p>Styliform appendages or lacinix — a pair of free, chitinous, apically bifurcated rods retractible near bases of and ensheathed by the <i>galea</i>.</p> <p>Labium — <i>mentum</i> oblong; <i>prementum</i> divided; <i>ligula</i> — with pair of bilobed <i>paraglossæ</i> and spinning organs; simple or two-lobed <i>palpi</i>.</p> <p>Hypopharynx — well developed, complex.</p>	<p>Digestive System.</p> <p><i>Alimentary canal</i> — <i>oesophagus</i> slender, extending into the enlarged abdominal U-shaped <i>stomach</i>; <i>hind intestine</i> short, ringed; <i>Malpighian tubes</i> four, somewhat curled. Spinning and salivary glands arise in the abdomen and open in the labium.</p> <p><i>Rectal papillæ</i> prominent.</p> <p>Nervous System.</p> <p>Compact, large <i>oesophageal ganglion</i> and <i>suboesophageal ganglion</i> in head; ganglion in center of prothorax, two large partly fused ganglia for the meso- and metathorax, and the third ganglion center at the convergence of the thorax and abdomen. Connectives short and double, extend posteriorly beyond the ganglia.</p> <p>Respiratory System.</p> <p><i>Spiracles</i> — two to three thoracic and six to seven abdominal, connected on each side by a large trunk.</p> <p>Reproductive System.</p> <p><i>Male</i> — a pair of simple, oval <i>testes</i>; <i>vas deferens</i> short, opening into a complex two-chambered <i>copulatory sac</i>, which communicates with the copulatory organ. Accessory glands present.</p> <p><i>Female</i> — simple, each <i>ovary</i> with three to five polytrophic ovarioles; oviducts short, <i>spermatheca</i> small, globular, opens into the dorsum of <i>vagina</i>. Accessory glands present.</p>
<p>Thorax.</p> <p><i>Prothorax</i> — greatly reduced and neck-like in winged forms; <i>meso-</i> and <i>metathorax</i> larger, separated or fused together.</p> <p><i>Legs</i> — normally slender, similar; <i>femora</i> of some apterous forms greatly enlarged; <i>tarsi</i> — two- to three-segmented; a pair of <i>claws</i> — simple or with one or more teeth visible.</p> <p><i>Wings</i> — absent or two pairs, hind pair much smaller; clear or partly clouded; venation relatively simple, some veins strongly curved; <i>pterostigma</i> present in fore wings; folded roof-like; smooth or hairy; vestigial or fore pair represented by scales.</p>	

ANATOMICAL CHARACTERS—*Continued*

<i>External Anatomy</i>	<i>Internal Anatomy</i>
<p><i>Thorax</i>—<i>continued</i> <i>Spiracles</i> — two or three pairs. <i>Abdomen</i> — short, 10-segmented, first segment may be greatly reduced and not easily visible. <i>Spiracles</i> — six pairs on first six segments. <i>Cerci</i> — absent. <i>Genitalia</i> — not prominent. <i>Male</i> with a pair of dorsal and ventral hooks.</p>	

Out of doors they are to be found on the ground among leaves and litter; on shrubs, trees, fences, hay, twigs; in nests of birds, rodents, wasps, ants; and on fungi. Their food is variable and consists of almost every sort of vegetable and animal debris, algæ, fungi, lichens, bark, nuts, seeds, and refuse in general.

The adults may be either winged, apterous, or the fore wings represented by scales. Those frequenting habitations are usually of the two latter types. They usually remain quite motionless, then suddenly run rapidly, often in a jerky and uncertain manner, and fly readily in warm weather. The short, compact body, large head, bead-like antennæ, and unusual gait set them apart from other insects. The somewhat drooping, roof-like wings and the little colonies or families living under a thin and delicate web also help to identify them. Ocelli are present in the alate forms, and in some brachypterous forms they are arranged in a triangle, the front ocellus being smaller than the two posterior ones.

The mouth parts are typically chewing but have, in addition, a pair of long, slender, toothed, retractile rods variously called styliform appendages, chisels, or lacinix near the maxillæ which are supposedly used in procuring food. The spinning tubes are located on the inner sides of lobe-like labial palpi in the position of the glossæ. The webs spun by psocids are very interesting. They may appear transparent, gray, or black and assume the form of filmy tents under which the entire family lives, or they may form thin or compact coverings over the masses of eggs.

Wings may be present in both sexes or in the male only. Brachypterous forms occur in otherwise normally winged species or may be the natural condition of certain groups. The atrophied wings may be scale-like and hairy. Many species are wholly apterous. The bodies and wings are frequently clothed with long and short, fine and coarse hairs while others are quite devoid of any vestiture. The wings may also be spotted in a more or less definite pattern.

Adult psocids are able to produce a faint but distinct tapping sound by striking the venter of the body against a resonant sounding board such as thin sheets of dry wood, loose wallpaper, and similar objects. Some observers have

reported such tappings so numerous and constant in old wooden houses as to be most annoying. There is an old and persistent superstition that these insects are responsible for the louder ticking of the death watch, prophet of death: "The solemn Death-watch clicks the hour of death."¹

The eggs are often elongate oval, smooth, or faintly sculptured, pale-colored, dark, or mottled and covered with webbing or a cement-like secretion in which minute particles passed through the alimentary canal are included. They may be laid singly or in groups of but a few to 20 or up to 130 by a single female. Parthenogenetical reproduction also occurs in the order and has been observed specifically in the case of the common book louse, *Liposcelis divinatorius* (Müller) (Rosewall, 1930).

The young appear very much like the adults and are usually associated with the parents. In many species the large C-shaped stomach is plainly visible in the transparent bodies of living individuals.

Some species, like the apterous *Liposcelis divinatorius* (Müller) and the scale-winged *Lepinotus inquilinus* Heyden, which inhabit buildings, may continue to breed throughout the entire year. Others like *Cæcilius obsoletus* (Stephens) and *Lachesilla pedicularia* (Linn.) may have several generations a year. *Cæcilius flavidus* (Stephens) has two or three generations a year. *Nymphopsocus destructor* Enderlein and *Stenopsocus immaculatus* (Stephens) may have two generations a year. *Trogium pulsatorium* (Linn.), *Philotarsus flaviceps* (Stephens), and many others have but one generation a year in northern Europe.

Because of their small size and fragile bodies psocids have not been found extensively in fossil remains. Some 28 species have been taken in Baltic Amber (Oligocene), one species from Sicilian Amber (Middle Miocene), 12 or more species from Copal, and a specimen of *Paropsocus* Scudder from the Oligocene of White River, Colo. The families represented are PSOCIDÆ, CÆCILIIDÆ, AMPHIENTOMIDÆ, LIPOSCOLIDÆ, and ATROPIDÆ.

Although this is not a large order of insects, there are probably many more genera and species yet to be described. Imms (1934) gives the number of known species at about 650, Handlirsch (1925), 700, and Muesebeck (1937) 875. There are probably no less than 200 or 250 genera. The distribution is worldwide, and representatives may be found in almost every locality.

The classification is based largely upon wing characters but the number of segments of the tarsi and labial palpi, the vestiture, the absence or presence and position of ocelli, length of the antennæ, the color, and many other characters are used. The system adopted is a modification of that used by Enderlein (1927) and Brues and Melander (1932).

COLLECTING, PRESERVING, AND MOUNTING

These insects may be taken by sifting leaves, straw, and other debris; by examining fungi; by removing the bark scales of living trees and the bark of dead logs; by sweeping grasses, weeds, and low shrubbery; and by beating

¹ Cowan, F., *Curious History of Insects* (Lippincott, Philadelphia): viii + 396, 1865. The real culprits are beetles of the family ANOBIIDÆ, pp. 58-61.

shrubs and trees of all kinds. They may be preserved dry and mounted directly upon pins or points; they may be preserved in liquid (alcohol, formalin,

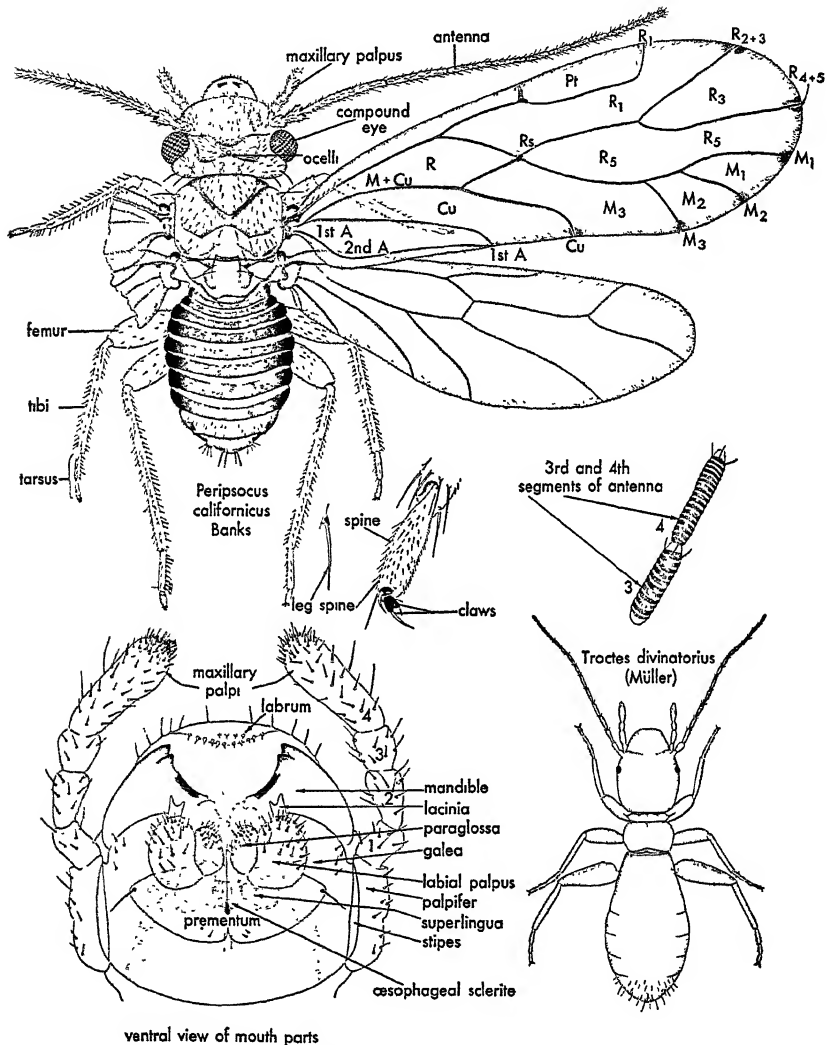


FIG. 69. CORRODENTIA or barklice.

lactic acid, or other preservative) in small vials; or they may be cleared, stained, and mounted on glass microscopic slides in chloral hydrate-gum arabic (Berlese or Faure media), balsam, euparal, or similar media as directed for COCCOIDEA and APHIDOIDEA.

KEY TO SUBORDERS

1. Larvæ, nymphs, and adults with two-segmented tarsi; labial palpi one-segmented (DIMERA) ISOTECNOMERA
2. Larvæ and nymphs with two-segmented tarsi; adults with three-segmented tarsi; labial palpi two-segmented (MYOPSOCIDÆ and MESOPSOCIDÆ one-segmented) (TRIMERA) HETEROTECNOMERA

I. Suborder ISOTECNOMERA Enderlein 1927

(I'so-tec-nom'e-ra, from the Greek *ἴσος*, equal, + *τεχνή*, pertaining to, + *μηρός*, thigh; referring to the equal number of tarsal segments in all stages.)

1. Family PSOCIDÆ Leach 1815
2. " CÆCILIIDÆ Kolbe 1884
3. " THYRSOPHORIDÆ Enderlein 1903
4. " ARCHIPSOCIDÆ Enderlein 1927

II. Suborder HETEROTECNOMERA Enderlein 1927

(Het'er-o-tec-nom'e-ra, from the Greek *ἕτερος*, different, + *τέχνη*, system, formation, + *μηρός*, thigh; referring to the unequal number of tarsal segments.)

5. Family MESOPSOCIDÆ Enderlein 1903
6. " AMPHIENTOMIDÆ Enderlein 1903
7. " MYOPSOCIDÆ Enderlein 1901
8. " LIPOSCELIDÆ Enderlein 1911 (TROCTIDÆ Endl. 1903)
9. " PSYLLIPSOCIDÆ Enderlein 1911
10. " ATROPIDÆ Kolbe 1884 (TROGIIDÆ Enderlein 1911)
11. " EMPHERIIDÆ Kolbe 1884
12. " LEPIDOPSOCIDÆ Enderlein 1911
13. " PSOQUILLIDÆ Kolbe 1884
14. " PERIENTOMIDÆ Enderlein 1927
15. " LEPIDILLIDÆ Enderlein 1911

Family PSOCIDÆ (Leach 1815) Samouelle 1819 (Psoc'i-dæ, from the Greek *ψαχω*, to rub small or fine; referring to the feeding habits of these insects in reducing food materials to powder). Psocids.

This is the dominant and most widely distributed family. The genus *Psocus* Latr. 1796 is also one of the most important in the family and is represented by at least 41 species in the United States (Chapman, 1930). Of these the most widely distributed ones are *P. confraternus* Banks, *P. inornatus* Aaron, *P. leidy* Aaron, *P. novæscotiæ* Walker, and *P. venosus* Burmeister. *P. oregonus* Banks is one of the common Pacific coast species. *P. taprobanes* Hagen is an abundant species in southern Asia and occurs in tea and cinchona plantations. *Stenopsocus stigmaticus* Imhoff and Labrun is a well-known European species which

frequents the apple trees and shrubs in England and feeds on lichens, algæ, fungi, and dead insects.

Family CÆCILIIDÆ Kolbe 1884 (Cæ'ci-li'i-dæ, from the Latin *cæcilia*, a kind of lizard).

Winged species with very small prothorax and two-segmented tarsi. A large group having a cosmopolitan distribution. *Lachesilla pedicularia* (Linn.) is one of the best known species. It is dark brown and black, 1.5 mm. long, and frequents old wood, plants, flowers, straw, birds' nests, and debris in general. It is the commonest species in houses in Europe and has been introduced into Australia. *Cæcilius aurantiacus* Hagen, a brownish species 2.4 mm. long, is one of the most familiar psocids in the United States.

Family LIPOSCELIDÆ Enderlein 1911 (**TROCTIDÆ** Endl. 1903) (Lip'o-scel'i-dæ, from the Greek *λείπω*, to lack, + *σκελς*, rib, side, segment; referring to the fusion of the mesothorax and metathorax).

A family of important wingless and winged species having the prothorax divided into two parts and the meso- and metathorax closely fused, and segment III of the maxillary palpi without sense organs. The small wingless species commonly known as the death watch and more appropriately called the book louse or cereal psocid, *Liposcelis* (*Troctes*) *divinatorius* (Müller), one of the smallest insects, measuring but 1 mm. in length, has been carried to all parts of the civilized world. It is one of the oldest known insects and has been associated with man from earliest times. In old wooden houses it often became exceedingly abundant because it found protection and an inexhaustible supply of food in the form of vegetable and animal debris, old wood, molds, and cereal products. It breeds throughout the year and is able to produce a faint ticking noise by striking the breast against dry wood or paper. The beats were long associated with the tapping of the death-watch beetle and thought to portend death of some occupant of the house.

This species is probably the most troublesome and destructive one in the order because of its omnivorous food habits and capacity for reproduction. It occurs in nearly every building, and, although generally nocturnal, it may be found wandering about at almost any time. Frequently it swarms in very great numbers and may injure the bindings of books, thereby getting the name "book louse." It also occurs in prepared cereals of all kinds and causes a large amount of waste in the destruction of the same merely by contamination. In museums it is a pest of some importance to herbarium specimens, to stuffed animals, and especially to dry pinned and mounted specimens, from which habits it has also been called the cabinet mite. In warehouses, granaries, stores, and other food repositories throughout the world, this tiny psocid is a constant worry and annoyance although it consumes but little food.

Liposcelis corrodens Heymons and *L. virgulatus* Pearman also occur in houses and warehouses in Europe, and *L. formicarius* (Hagen) inhabits ants' nests.

Family ATROPIDÆ Kolbe 1884 (TROGIIDÆ Enderlein 1911) (A-trop'i-dæ, from Atropos, in Greek mythology that one of the three Fates who cuts off the thread of life, represented in art with a pair of scales or shears; referring to the "death watch" which was supposed to portend death).

Species in which the wings are wholly absent or only the fore wings are represented by small scales without venation; the tarsi three-segmented; prothorax large and divided into three parts; meso- and metathorax separated by a suture. This is also an important family of wide distribution.

Atropos pulsatorium (Linn.) is a minute, pale-colored species, 1.5-2.0 mm. long, occurring in houses, libraries, museums, and other structures, as well as out of doors in deserted beehives and nests of wasps of the genus *Polistes*. Its life history and habits are very similar to those of the death watch or cereal psocid. It has been introduced into North America, Australia, and probably other continents.

Lepinotus inquilinus Heyden, *L. reticulatus* Enderlein, and *Pteroxanium squamosum* Endl. have wing scales and frequent dwellings as well as out of doors in Europe. The first of these has been introduced into Australia. All are pests in museums, libraries, and dwellings.

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CHAPTER XX

17. Order MALLOPHAGA¹ Nitzsch 1818

(Mal-loph'a-ga, from the Greek *μαλλός*, a lock of wool, + *φαγεῖν*, to eat; because of their feeding upon wool and hair.) German, Federlinge, Haarlinge, Pelzfresser. French, Mallophages.

Bird Lice, Biting Bird Lice.

Small, apterous, ectoparasitic, active insects with simple metamorphosis and modified, biting mouth parts; body broad or elongate, flattened dorsally, tough, and well chitinized; head hypognathous, free, broad, somewhat triangular in outline; antennæ short, setiform or clavate, three- to five-segmented; compound eyes reduced; ocelli absent; thorax narrow and fused; legs short; claws absent or if present one or two stout, simple or specialized for clasping hairs and feathers; cerci absent.

The members of this rather large order are small wingless insects with simple or incomplete metamorphosis and biting mouth parts. The bodies are heavily or weakly chitinized, flattened, and usually have broad heads with short antennæ which are free and exposed or concealed in a groove beneath. The color varies from white to yellow, tan, brown, dark reddish, or almost black, with or without distinctive markings. Most are swift runners and are fitted with claws and hairs to enable them to pass rapidly through hairs and feathers of the host, but others are quite slow and cling to the feathers by their jaws. In habits they are ectoparasitic, living on warm-blooded animals including chiefly birds, but quite a number live also on mammals. They feed upon the hair, feathers, epidermal scales, and the dried blood collecting around wounds of the host and, while they do not actually attack the flesh, they become very irritating and are often present in sufficient numbers to cause great discomfort and even death.

¹ Linnæus (*Systema Naturæ*, ed. 10, 1758) placed these insects in his order APTERA which was a repository for other apterous insects of many orders as well as for members of the classes CRUSTACEA, CHILOPODA, and DIPLOPODA. Latreille (1802, III: 72-73) limited the APTERA to include insects only and erected the new order PARASITA for the genera *Ricinus* and *Pediculus*. Leach (1815) created the order ANOPLURA to replace PARASITA of Latreille and in it included his two families PEDICULIDES and NIRMIDES. According to Samouelle (1819) "This name [PARASITA] Dr. Leach has changed for the sake of harmony and also to render the name more easy of retention in memory, the characters being drawn from the same parts." Nitzsch (1818) established the name MALLOPHAGA for the bird lice and biting lice as here used, and his name has precedence over all others. He not only grouped these insects under the one name but also divided the members into four important genera and 10 subgenera. The name *LIPOPTERA* Shipley (1904) has not been accepted by recent authors. If the orders MALLOPHAGA and ANOPLURA, as used in this text, are combined into a single order, as is now being done by some systematists, Latreille's name PARASITA would have priority.

As they cannot fly, they are distributed largely by personal contact or from the nests and roosts to the young and to other species. As they are able to live but a short time away from a warm-blooded host, it is not clear how some species have become so widely distributed among the different hosts.

The elongated eggs or nits are glued singly on the hairs or feathers of the host, and the young appear much the same as the adults. They breed under

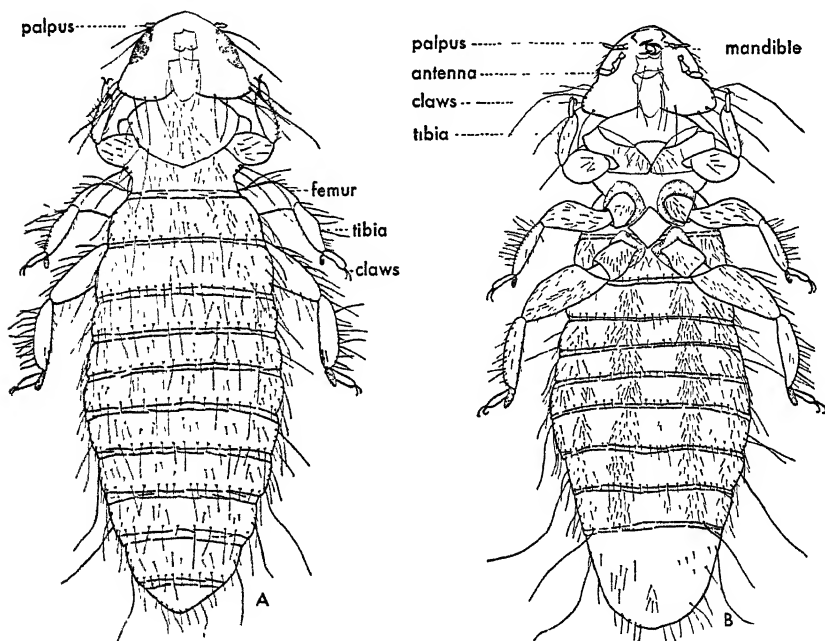


FIG. 70. Large poultry louse, *Menopon stramineum* Nitzsch. A, dorsal aspect; B, ventral aspect.

very favorable conditions, having a fairly uniform heat from the body of the host to make them comfortable under most climatic conditions. The broods are overlapping, and there are several to many generations a year.

The chief damage to the host is through constant irritation. The species affecting sheep and goats are responsible for a considerable financial loss, since they partially cut or weaken fiber of the wool, thus reducing its length and quality.

According to Tillyard, no fossils of this order have yet been discovered.

The members of the order MALLOPHAGA have a very wide distribution because of the great range of many of the hosts, especially birds, upon which they live. Beier (1936) lists 2,000 described species, there being no less than 500 species in Germany alone. Muesebeck (1937) estimates that there are 2,500 described species.

IMPORTANT ANATOMICAL CHARACTERS

External	Internal
<p>Size — small, 2–6 mm., seldom more than 10 mm. long.</p> <p>Shape — oval or elongate, flattened dorso-ventrally.</p> <p>Integument — tough, elastic; heavily chitinized; smooth, hairy, or spiny.</p> <p>Color — various shades of yellow, brown, gray, black, or spotted.</p> <p>Head — free, horizontal, flattened, large, somewhat triangular in form, normal or emarginate, often strongly chitinized.</p> <p>Antennæ — short, filiform, or clubbed, free or concealed in a groove on ventral side of head; two- to five-segmented.</p> <p>Compound eyes — greatly reduced.</p> <p>Ocelli — absent.</p> <p>Mouth parts — ventral, modified for piercing and biting. <i>Labrum</i> — with base wider than head.</p> <p>Mandibles — strong, sharp, horizontal or vertical, asymmetrical, three-toothed.</p> <p>Maxillæ — reduced, simple lobes attached laterally to labium; <i>palpi</i> absent or four-segmented.</p> <p>Styliform rods — delicate, similar to those of CORRODENTIA.</p> <p>Labium — submentum, mentum, and simple lobed palpi; <i>ligula</i> — simple or two-lobed and with processes similar to the paraglossæ; <i>palpi</i> — rudimentary.</p> <p>Œsophageal sclerite — anterior portion of the Œsophagus. <i>Hypopharynx</i> — modified, prominent, complex, often with rod-like stalks.</p> <p>Thorax — <i>Prothorax</i> — usually narrower than head; free, or fused with mesothorax. <i>Meso-</i> and <i>metathorax</i> — fused or separated by a suture; metathorax may resemble the prothorax inverted in size and shape.</p> <p>Legs — short and stout or fairly long and slender. <i>Tarsi</i> — one- to two-segmented, without claws or with one or two claws.</p> <p>Claws — curved, simple or modified for grasping hairs or feathers.</p> <p>Spiracles — ventral — one pair prothoracic.</p>	<p>Digestive System.</p> <p><i>Alimentary canal</i> — straight, tubular or convoluted, short.</p> <p><i>Œsophagus</i> — expands into enlarged, well-developed <i>crop</i> which is connected by slender tube or lies at one side of alimentary canal.</p> <p><i>Mid-intestine</i> — large.</p> <p><i>Enteric cæca</i> — large pair from the stomach.</p> <p><i>Hind intestine</i> — short, simple.</p> <p><i>Malpighian tubules</i> — four.</p> <p><i>Rectal papillæ</i> — six in a whorl.</p> <p><i>Salivary glands</i> — two pairs, well developed; unite and open into pharynx.</p> <p>Respiratory System. Ordinary.</p> <p><i>Spiracles</i> — six to seven pairs.</p> <p><i>Prothoracic</i> — one pair.</p> <p><i>Abdominal</i> — five or six pairs on segments III to VIII, II to VII, or III to VII (<i>Trimenopon</i> and <i>Gliricola</i>).</p> <p>Nervous System. Well developed. Head ganglia often large and united to thoracic group by short, stout connectives; three thoracic ganglia joined without connectives; no abdominal ganglia.</p> <p>Circulatory System.</p> <p><i>Heart</i> located in abdominal segment VII or in VII to VIII; short, with two or three pairs of ostia; <i>Aorta</i> swollen at base. <i>Pulse</i> — 120 beats per minute at 50°C (Fulmek, 1907).</p> <p>Reproductive System.</p> <p><i>Male</i> — with two to three oval or pyriform separated follicles. <i>Vesicula seminalis</i> — compact, bilobed, extending into winding ejaculatory duct.</p> <p><i>Female</i> — ovaries, one pair, each consisting of five panoistic ovarioles; <i>vagina</i> — opens behind sternite 7. <i>Accessory glands</i> and <i>spermatheca</i> — present or absent.</p>

IMPORTANT ANATOMICAL CHARACTERS—*Continued*

<i>External</i>	<i>Internal</i>
Abdomen — regularly oval or nearly circular; elongated or parallel-sided; usually longer than head and thorax; tergite I may be absent; eight- to 10-segmented. Spiracles — five to six pairs on segments II to VII, III to VII, or III to VIII. Genitalia — genital openings in an invagination in the body wall. <i>Male</i> — ædeagus complex. <i>Female</i> — not evident. <i>Cerci</i> — absent.	

KEY TO SUBORDERS

1. Maxillary palpi four-segmented; antennæ normally four-segmented and distinctly clubbed or capitate and concealed in a groove on the underside of the head; mandibles horizontal; meso- and metathorax usually separated by a suture **AMBLYCERA**
2. Maxillary palpi absent; antennæ three- or five-segmented, setiform, not concealed in a groove; mandibles vertical; meso- and metathorax fused and without dividing suture **ISCHNOCERA** p. 199

Suborder **AMBLYCERA** Kellogg 1896

(Am'bly-cer'-a, from the Greek ἀμβλῦς, blunt, + κέρασ, horn; because of the presence of maxillary palpi?).

KEY TO FAMILIES¹

1. All tarsi with two claws (infesting birds) 2
 Tarsi of middle and hind legs with one claw or none; rarely two in forelegs; some tarsi modified as hair claspers; labial palpi one-segmented (infesting guinea pigs and other South American rodents) **GYROPIDÆ** p. 197
2. Antennæ capitate, five-segmented; legs long and slender; body clothed with stiff, slender spines (infesting kangaroos, wallabies, and occasionally dogs) **BOOPIIDÆ** p. 198
 Antennæ clavate, four-segmented 3
3. Prothorax and metathorax similar in size and shape, but inverted (infesting Central and South American rodents) . . . **TRIMENOPONIDÆ** p. 198
 Prothorax and metathorax normal; meso- and metathorax fused or separated by a suture. 4

¹ There is little uniformity among entomologists in the classification of these confusing insects. The total number of families varies from two to 10, and there is no agreement as to the exact placement of certain families in the different suborders. The system of Brues and Melander (1932) is adopted with some slight variations.

The suborder **RHYNCHOPHTHIRINI** has been erected by Ferris (*Parasitology* 23: 112-127, 1931) to include the elephant louse, *Hæmatomyzus elephantis* Piaget, which has generally been associated with the sucking lice in the order ANOPLURA.

4. Head evenly expanded behind, broadly triangular and strongly enlarged above the eyes (infesting poultry and other birds) **MENOPONIDÆ** p. 198
 Head not evenly expanded and broadly triangular, not enlarged above the eyes 5

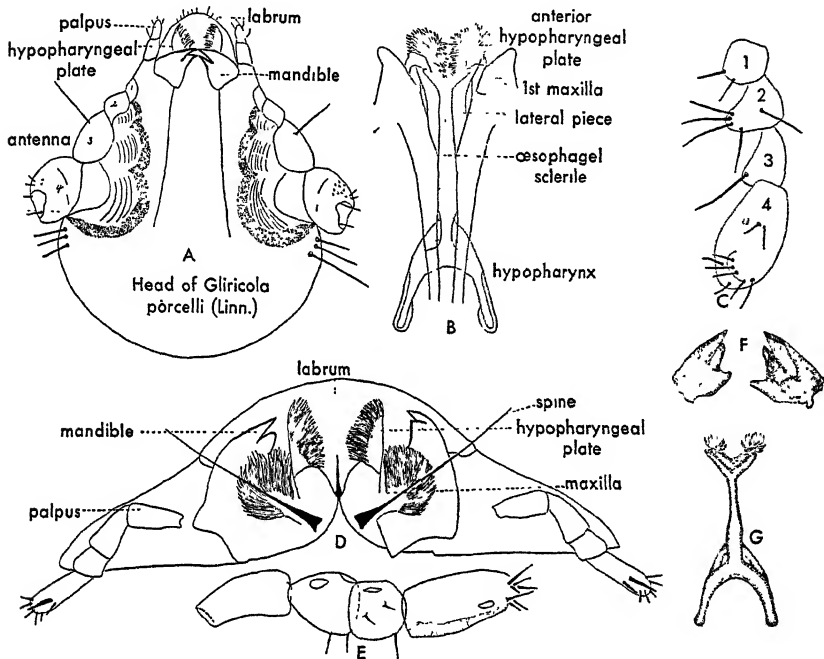


FIG. 71. Drawings of important anatomical parts of various biting bird lice. A, head of the guineapig louse, *Gliricola porcelli* (Linn.); B, portion of the mouth parts and C, antenna of *Ancistronea porcellira* Westwood (after Cummings, 1913); D, mouth parts and E, antenna of *Menopon stramineum* Nitzsch; F, hypopharyngeal plates of *Ancistronea vagelli* (Fab.) (after Snodgrass, 1899).

5. Sides of head with strong swelling in front of the eyes; spiracles on abdominal segments III to VIII, inclusive (infesting birds)

LÆMOBOTHRIIDÆ p. 199

- Sides of head straight or concave; spiracles on abdominal segments II to VII, inclusive (infesting birds) **RICINIDÆ** p. 199

Family GYROPIDÆ Kellogg 1908 (Gy-rop'i-dæ, from the Greek γύρος, a ring, circle, + ποῦς, foot; from the hair-clasping feet). Biting Guinea Pig Lice.

A small family of Central and South American species infesting rodents. Two species, the guinea pig louse, *Gliricola porcelli* (Linn.) (*Gyropus gracilis* Nitzsch), and the oval guinea pig louse, *Gyropus ovalis* Nitzsch, infest guinea

pigs and have become widely distributed through the extensive use of these animals for experimental purposes.

Family BOOPIIDÆ Mjöberg 1910 (Boop-i'-i-dæ, from the Greek *βοῶπις*, ox-eyed; referring to the relatively large eyes). Biting Kangaroo Lice.

A small family composed of four genera and 13 species, all infesting kangaroos and wallabies and confined to Australia. The genus *Boopis* Piaget con-

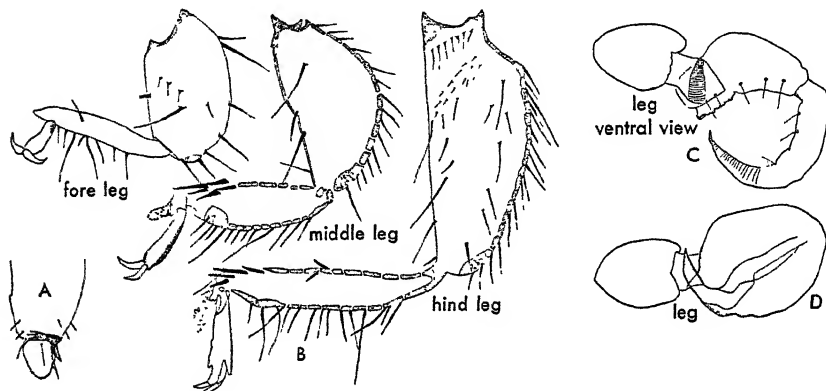


FIG. 72. Anatomical parts of biting bird lice. A, clawless tarsus of *Gliricola porcelli* (Linn.); B, legs of *Menopon stramineum* Nitzsch; C, leg of *Gyropus ovalis* Nitzsch extended and D, same folded.

tains eight species having four-segmented palpi. The two species of *Latumcephalum* Le Soûef have two-segmented palpi. The members of the genus *Heterodoxus* Le Soûef and Bullen have spines on the underside of the head and constitute two species.

Family TRIMENOPONIDÆ Harrison 1917 (Tri-men'o-pon'i-dæ, from the Greek *τρία*, three, + *Menopon*; referring to the three thoracic segments).

A small family including the genera: *Harrisonia* Ferris, *Trimenopon* Cummings, *Philandesia* Kell. and Nakayama, and *Cummingsia* Ferris occurring on rodents in Central and South America.

Family MENOPONIDÆ Mjöberg 1910 (Men-o-pon'i-dæ, from the Greek *μένω*, to remain, + *πόνος*, pain; because of their annoyance to the hosts?). Biting Bird Lice.

A large family of widely distributed species infesting birds and particularly troublesome to domestic fowls. Among the most important species are the common hen louse, *Menopon gallinæ* Linn. (*M. pallidum* Nitzsch), a small, pale-yellow species 1.0–1.5 mm. long, which infests poultry including chickens, ducks, and pigeons and is probably the most destructive member in the order;

and the large poultry louse, *M. stramineum* Nitzsch, which is more elongate and 2.0–2.5 mm. long. It infests chickens, turkeys, peacocks, and pigeons.

The giant bird louse, *Ancistrana vagelli* (Fab.), is the broadest known species. It occurs on sea birds: shearwaters and fulmars in North America and Europe.

Family LÆMOBOTHRIIDÆ Mjöberg 1910 (Læ'mo-both-ri'i-dæ, from the Greek λαιμός, throat (connection with, or relation to, the œsophagus or pharynx), + βόθρος, a trench; referring to the small throat).

A small family, of which the dominant genus, *Læmobothrion* Nitzsch, occurs on aquatic birds (geese and coots) in the north temperate regions of North America, Europe, and Asia as well as parts of Africa and South America.

Family RICINIDÆ¹ Enderlein 1927 (Ri-cin'i-dæ, from the Latin *ricinus*, literally a kind of vermin that infests sheep, dogs, and other animals; a tick).

An important family embracing several genera, including *Ricinus* De Geer, *Docophorus* Nitzsch, and *Trochilæctes* Paine and Mann, infesting a large variety of land and water birds.

Suborder ISCHNOCERA Kellogg 1896

(Isch-noc'er-a, from the Greek ισχνός, weak, thin, + κέρα, horn; because of the absence of maxillary palpi?).

KEY TO FAMILIES

1. Tarsi with a single claw; antennæ three-segmented in the male and usually in the female (infesting mammals; rodents, carnivores, ungulates) **TRICHODECTIDÆ**
- Tarsi with a pair of claws; antennæ five-segmented 2
2. Bird-infesting species 3
- Animal-infesting species; last antennal segment clavate or capitate; sides of forehead with stout, recurved hooks (infesting the mouse lemurs of Madagascar) **TRICHOPTERIDÆ** p. 200
3. Meso- and metathorax separated by a suture; eyes deeply constricted (infesting penguins on Kerguelen Island in the Southern Ocean) **NESIOTINIDÆ**
- Meso- and metathorax completely fused, not separated by a distinct suture; head without recurved hooks (infesting birds and cosmopolitan in distribution) **PHILOPTERIDÆ** p. 200

Family TRICHODECTIDÆ Kellogg 1908 (Trich'o-dec'ti-dæ, from the Greek θρίξ, τριχός, hair, + δέκτης, one who takes from, one who bites; referring to their parasitic feeding habits which may result in loss of the hair).

One of the most injurious families in the order because many of the species infest and greatly annoy domestic animals. The economic species have been widely distributed throughout the world through commerce and are to be

¹ The LEIOTHEIDÆ or LIOOTHEIDÆ Burmeister of some authors.

found wherever the hosts are common. Other species are to be found upon many kinds of wild animals. The most important domestic species are:

Cattle red louse, *Trichodectes bovis* (Linn.) (*T. scalaris* Nitzsch).

Biting horse louse, *T. equi* Linn. (*T. parumpilosus* Piaget).

Pilose biting horse louse, *T. pilosus* Geb.

Biting sheep louse, *T. ovis* Linn. (*T. sphærocephalus* Olfers).

Biting dog louse, *T. canis* De Geer (*T. latus* Nitzsch).

Biting goat louse, *Bovicola capræ* (Gurlt) (*Trichodectes*, *T. climax* Nitzsch).

Biting cat louse, *Felicola subrostratus* (Nitzsch) (*Trichodectes*).

Family TRICHOPTILOPTERIDÆ Brues and Melander 1932 (Trich'o-phil'-op-ter'i-dæ, from the Greek *τριξ*, *τριχός*, hair, + *Philopterus*, a family closely related to the PHILOPTERIDÆ whose members may feed upon hair and scales).

Species of the genus *Trichophilopterus* Stobbe infest mammals.

Family PHILOPTERIDÆ¹ Burmeister 1838 (Phil'op-ter'i-dæ, from the Greek *φίλος*, loving, fond of, attached to, + *πτερά*, wings, feathers; referring to their infesting birds).

The largest and one of the most important families in the order. The major genera are *Degeeriella* Neumann (*Nirmus* Hermann 1804), *Esthiopterum* Harrison, *Gonicotes* Nitzsch, *Goniodes* Nitzsch, *Lipeurus* Nitzsch, and *Philopterus* Nitzsch.

The hosts include members of practically all kinds of land and water birds and are pests of many domestic birds and poultry.

Among the commonest domestic species are the following:

Pigeon louse, *Columbicola columbæ* (Linn.) (*Esthiopterum*, *Lipeurus buculus* Nitzsch).

Squalid duck louse, *E. crassicorne* (Scopoli) (*Lipeurus squalidus* Nitzsch).



FIG. 73. Eggs of mallophagans. A, chicken head louse, *Lipeurus heterographus* Nitzsch; B, large poultry louse, *Menopon biserialatum* Nitzsch. (After Mote, 1911.)

White swan louse, *Ornithobius cygni* (Linn.).

European pigeon louse, *Gonicotes bidentatus* Scopoli.

Large chicken louse, *G. gigas* Taschenberg.

Lesser chicken louse, *G. hologaster* Nitzsch.

Dissimilar chicken louse, *Goniodes dissimilis* Nitzsch.

¹ Enderlein (1927) has divided this family into the following families: LIPEURIDÆ Mjöberg 1910, EURYMETOPIDÆ Mjöberg 1910, and GONIODIDÆ Mjöberg 1910. The name NIRMIDÆ Samouelle 1819 (NIRMIDES Leach 1818) has also been used as a family name for this group.

Horned pigeon louse, *G. damicornis* Nitzsch.

Small pigeon louse, *G. minor* Piaget.

Peacock lice, *G. parviceps* Piaget and *G. pavonis* (Linn.).

Variable chicken louse, *Lipecurus caponis* (Linn.).

Turkey louse, *Lipecurus gallipavonis* Geoffroy.

Mallophagans are usually quite restricted in their host requirements. Certain species like the biting dog louse are restricted to a single species of host while other species such as the pigeon louse, chicken louse, and cattle louse may infest species belonging to several related genera. Because of these intimate host relationships Kellogg (1913) called attention to the possibilities that mallophagans might serve as indicators of the relationships of certain hosts and suggested a natural law that when closely related species of biting bird lice occur on more than one host then these hosts are also likely to be closely related. Following this line of thought Harrison (1915) pointed out the fact that the mallophagan species belonging to the genus *Aptericola* Harrison which infest the New Zealand Kiwis, *Apteryx* spp., are at most but a subgenus of *Rallicola* Johnston and Harrison whose species commonly infest rails and that this circumstance indicates that the Kiwis which have long been associated with the flightless birds are according to Kellogg's law more closely related to the crane-like birds belonging to an entirely different division. This suggested relationship appears now to have been confirmed by studies in avian morphology.

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CHAPTER XXI

18. Order ANOPLURA¹ Leach 1815

(An'o-plu'ra, from the Greek *ἀνοπλος*, unarmed, + *σύρα*, tail; referring to the rather naked and tailless condition.)
German, Läuse. French, Poux.

True Lice, Sucking Lice.

Minute to small, flattened, elongated, or crab-like apterous insects with simple metamorphosis; mouth parts piercing and sucking, retractile, with fleshy unsegmented rostrum; integument tough and elastic; head small; compound eyes reduced or absent; ocelli absent; thorax narrow and partly fused; legs short, stout, with one-segmented tarsi and single claws usually specialized for grasping hairs; abdomen oval or somewhat circular, nine-segmented; cerci absent. Permanently ectoparasitic on mammals.

IMPORTANT ANATOMICAL CHARACTERS

<i>External</i>	<i>Internal</i>
Size — minute to small. 0.35–6.50 mm. long.	Digestive System.
Shape — long, slender, oval, or crab-like; flattened dorsally.	<i>Alimentary canal</i> — buccal funnel is the anterior part of the <i>fore intestine</i> ; <i>oesophagus</i> passes directly to the <i>stomach</i> , which occupies most of the abdomen.
Integument — tough and elastic, partly chitinated, smooth, hairy, or scaly.	<i>Enteric cæca</i> — present in <i>Pediculus</i> .
Color — mostly pale or gray; chitinated areas yellow, brown, or dusky.	<i>Hind intestine</i> — straight.
Head — small, narrow, pointed, prognathous.	<i>Malpighian tubes</i> — four.
<i>Antennæ</i> — setiform, short, three- or	<i>Rectal papillæ</i> — six in a whorl.
	<i>Salivary glands</i> — two pairs in thorax;

¹ The author is following general practice in using the name ANOPLURA for this group of insects, but would like to call attention to the following facts:

The order PARASITA, erected by Latreille in 1802 to include the biting lice and the sucking lice, can no more be ignored than the Linnæan orders NEUROPTERA and HEMIPTERA which have been divided to form new orders, but which still have been retained for at least a part of the heterogenous group originally included under those names. Since the bird lice were separated off into a new order, MALLOPHAGA, by Nitzsch in 1818 before Latreille, in 1825, redefined the PARASITA by dividing the members into the two families or groups MANDIBULATA, or biting bird lice, and SIPHUNCULATA, or sucking lice, it is only following the accepted laws of priority to retain the name PARASITA for the sucking lice wherever, as in this work, these insects are placed in a separate and distinct order. In accordance with this arrangement, such names as ANOPLURA Leach 1815, SIPHUNCULATA Latreille 1825, Meinert 1891, PEDICULINA Burmeister 1835, PEDICULIDA Mayer 1876, POLYPTERA Banks 1892, and PEDICULOIDA Crampton 1921 fall as synonyms. Comstock and Comstock (1895) were among the first of modern entomologists to adopt the name PARASITA exclusively for the sucking lice, but only as a suborder of the order HEMIPTERA. This lead was followed by Essig (1913). Osborn (1923) placed them in the suborder PARASITICA in the order HEMIPTERA, a system followed by a number of other systematists.

IMPORTANT ANATOMICAL CHARACTERS—*Continued*

<i>External</i>	<i>Internal</i>
<p>five-segmented (three-segmented in first instar of <i>Pediculus</i> and <i>Phthirus</i> and five-segmented in later instars).</p> <p><i>Eyes</i> — compound eyes present in forms attacking man (well developed, reduced, or vestigial); absent in other forms.</p> <p><i>Ocelli</i> — absent.</p> <p><i>Mouth parts</i> — piercing and sucking; modified into a prestomum, rostrum or sac tube, and a pharyngeal tube enclosing a pair of dorsal stylets and a single ventral stylet, all retractile within the head. In feeding, the sac tube contacts the skin, the stylets rupture the cells, the pharyngeal tube is inserted into the puncture and conveys blood into the buccal cavity by a pumping action.</p> <p><i>Thorax</i> — small; fused and with segmentation indistinct; usually narrower than abdomen.</p> <p><i>Legs</i> — short, stout; tarsi one-segmented and with a single long claw and usually an opposable process and pad for clinging to hairs.</p> <p><i>Spiracles</i> — one or two pairs, dorsal.</p> <p><i>Abdomen</i> — nine-segmented; narrow, oval, or broad; terga, pleura, and sterna chitinated and often pigmented.</p> <p><i>Spiracles</i> — six or seven pairs on segments III to VIII or II to VIII, inclusive.</p> <p><i>Genitalia</i> — <i>Male</i> — well developed. <i>Female</i> — pair of short gonopods used in grasping hairs during egg laying</p> <p><i>Cerci</i> — absent.</p>	<p>ducts from salivary canal empty just below dorsal stylets.</p> <p><i>Pawlowsky's glands</i> — secrete fluid to moisten stylets; empty into stylet sac.</p> <p>Respiratory System.</p> <p><i>Thoracic spiracles</i> — one or two pairs, dorsal.</p> <p><i>Abdominal spiracles</i> — six or seven pairs, one pair on each of abdominal segments III to VIII or II to VIII, inclusive.</p> <p>Nervous System.</p> <p>Head ganglia well developed.</p> <p>Thoracic and abdominal ganglia fused together.</p> <p>Reproductive System.</p> <p><i>Male</i> —</p> <p><i>Testes</i> — one pair, bilobed. <i>Vasa deferentia</i> — slender, open into <i>vesiculae seminales</i> or separately into ejaculatory duct.</p> <p><i>Female</i> —</p> <p><i>Ovaries</i> — five polytrophic ovarioles to each.</p> <p><i>Accessory glands</i> — present.</p> <p><i>Receptaculum seminis</i> — absent.</p>

Sucking lice are very small and rather slow-moving insects. The smallest species is probably *Microphthirus uncinatus* (Ferris). The male is but 0.35 mm. and the female 0.45 mm. long. The largest species is the **African wart hog louse**, *Hæmatopinus phacochæri* Enderlein, in which the male is 5.0 mm. and the female 6.5 mm. long. The human louse, *Pediculus humanus* Linn., a medium-sized species, averages 2.00–3.25 mm. in length.

Members of this order are quite homogenous and constitute a distinct group of insects both as to appearances and habits. Being permanently ectoparasitic on mammals, they occur generally wherever these animals live in the sea and on land. Species infesting domesticated animals have been carried to all parts

of the world and are now cosmopolitan. They are certainly as old as the human race and older than its domesticated animals.

The life history of most species is rather simple. Because of the uniformity of the body temperatures of the hosts, living conditions are fairly uniform throughout the year, and the most striking variations occur between tropical and polar climates and outdoor and indoor conditions during winters in the temperate and colder ranges of the hosts.

Sanitation of the body and living quarters have much to do with the abundance of these insects on man and on his domestic animals.

The most important hosts are:

Order PRIMATES: apes, man, monkeys.

Order UNGULATA (hoofed mammals): domesticated animals: cattle, goats, horses, sheep, elephants; wild animals: buffaloes, deer, sheep, elephants.

Order RODENTIA (rodents); domestic and wild: chipmunks, marmots, mice, prairie dogs, rabbits, hares, rats, squirrels, woodchucks.

Order CARNIVORA (carnivores, domestic and wild): land animals: dogs; marine animals: seals, sea elephants, sea leopards, sea lions, walruses.

Important animals immune from or only rarely infested by sucking lice:

Order MARSUPIALIA: kangaroos, wallabies, wombats, phalangers, opossums.

Order EDENTATA: sloths, anteaters, armadillos.

Order CARNIVORA, Family FELIDÆ: cats, cougars, jaguars, leopards, lions, lynxes, tigers.

Order INSECTIVORA: cobegs, moles, shrews, tenrecs.

Order CHIROPTERA: bats.

There are no marked changes in the development of an individual, but there are normally four instars during its life history. The eggs or nits are simple and oval or elongated without definite surface markings. The most remarkable thing about them is the manner in which some are attached to the hairs and wool of the hosts. They are arranged singly or in groups, usually near the skin of the host, and hatch in from a few days to a week or more. The young greatly resemble the adults but are usually paler in color. All living forms are rather slow, but move with sufficient speed and skill among the hairs and in clothing to give rise to the old saying: "You can't catch a louse with one finger." Reproduction occurs throughout the year, uninterrupted in the tropics and only slowed up during the winters in the colder regions. Under certain conditions in the health and physical state of the hosts, in the sanitation of their surroundings, and under favorable climatic environmental factors, some species of lice become so abundant as to injure the host greatly or destroy it completely. They either perish with the host or leave the cold body to seek other living animals. Thus the destruction of the host often means the dispersal of or the complete extinction of the lice. The actual presence and the effects of these insects on the host are known as *pediculosis*. The species infesting man carry and transmit certain serious and often fatal diseases such as typhus fever, trench fever, and relapsing fever, especially in concentration camps of refugees,

among soldiers during war maneuvers, in slums of large cities, and among primitive tribes.

Among civilized races lice rarely if ever occur in the habitations and on the persons of those who dwell under the influence of modern medical sanitary conditions.

The order comprises some 30 genera and about 500 species.

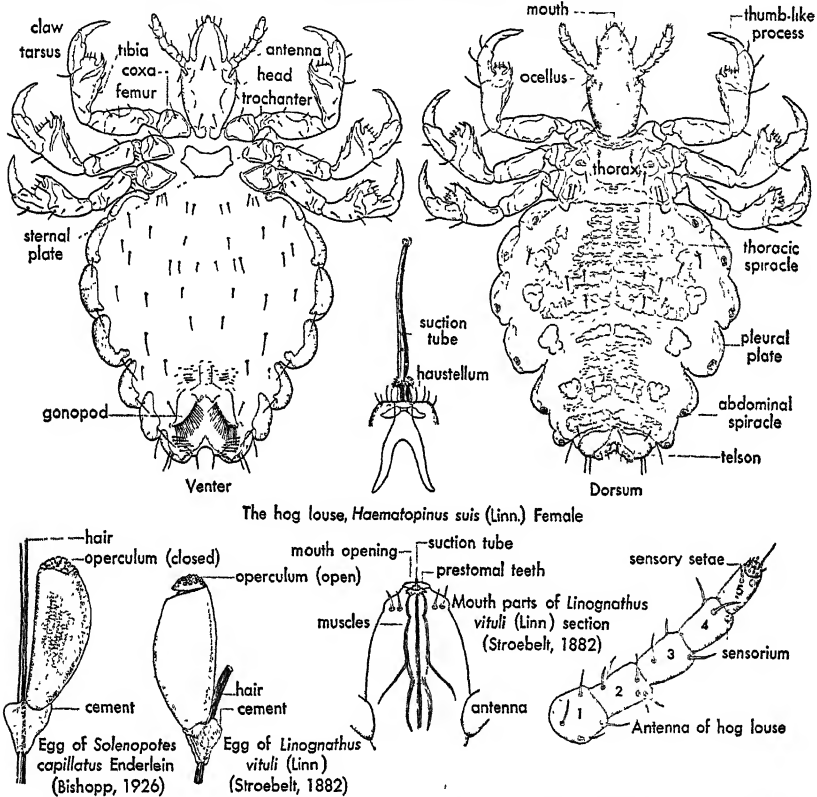


FIG. 74. ANOPLURA or sucking lice. The hog louse, *Haematopinus suis* (Linn.); eggs of the capillate cattle louse, *Solenopotes capillatus* Enderlein and the long-nosed ox louse, *Linognathus vituli* (Linn.); and mouth parts of the long-nosed ox louse. (Partly redrawn from Ferris.)

KEY TO FAMILIES

1. Body flattened; clothed with hairs or spines (rarely scales) in rows; seven pairs of spiracles, one pair on each of the mesothorax and abdominal segments III to VIII, inclusive; antennæ three- or five-segmented (infesting land mammals) 2
- Body robust; clothed with stout bristles or with spines and scales; nine pairs of spiracles — one pair on each of the mesothorax, metathorax,

- and abdominal segments II to VIII, inclusive; antennæ four- or five-segmented (infesting marine carnivores) . . . **ECHINOPHTHIRIDÆ**
2. Compound eyes well developed and pigmented; rostrum short; tibia and tarsus not separated by a distinct sclerite 4
Compound eyes absent or vestigial; rostrum very long; tibia and tarsus separated by a distinct sclerite (infesting many mammals, but not man) 5
3. Abdominal segments III and IV fused and with three pairs of spiracles close together; lateral marginal abdominal lobes present; crab-like in form (infesting man) **PTHIRIDÆ**
Abdominal segments free; spiracles normally located; without marginal abdominal lobes; generally slender in form (infesting man and monkeys) **PEDICULIDÆ**
4. Antennæ five-segmented (infesting sheep, goats, hogs, rodents, dogs, insectivores, etc.) **HÆMATOPINIDÆ** p. 208
Antennæ three-segmented (infesting rodents and monkeys) **HÆMATOPINOIDIDÆ** p. 209

Family ECHINOPHTHIRIDÆ Enderlein 1904 (E-chi'no-phthir-i'i-dæ, from the Greek ἐχῖνος, a hedgehog, + φθελρ, a louse; literally a spiny louse).

The members of this small family are mostly confined to four genera: *Ant-arctophthirius* Enderlein, *Echinophthirius* Giebel, *Lepidophthirius*¹ Endl., *Proechinophthirus* Ewing. They are characterized by many spines and hairs. They infest members of the family PHOCIDÆ, including seals, sea lions, and walruses in the arctic and antarctic regions.

Family PHTHIRIDÆ Brues and Melander 1932 (Phthi-ri'-dæ, from the Greek φθελρ, a louse).

This small family was erected for the single genus *Phthirus*² Leach 1815 and the species *P. pubis* (Linn.) (*P. inguinalis* Redi), which is commonly known as the crab louse, because of its shape and the enlarged claws on the middle and hind legs. The color is whitish, with a dusky patch on each shoulder and with reddish legs. The length varies from 1.5–2.0 mm. and the width is almost as much. This species, which is confined to man, inhabits the areas of stiff hairs on the body such as the pubic region, the armpits, the beard, and at times even the eyelashes and rarely the head. It is cosmopolitan and has been associated with man from ancient times.

Phthirus gorillæ Ewing infests the gorilla in the Belgian Congo, Africa

Family PEDICULIDÆ Samouelle 1819 (Ped'i-cu'-li-dæ, from the Latin *pediculus*, a louse).

This small family, including only three species, is particularly important because of its long and firm association with man and other primates.

¹ Some authors place the members of this genus in a separate family, **LEPIDOPHTHIRIDÆ** Mjöberg 1910, because of the scale-like spines on the body. It is represented by a single species, *Lepidophthirius macrorhini* Endl., on the south-sea elephant.

² Sometimes incorrectly spelled *Phthirius* and *Phthirus*.

The human louse, *Pediculus humanus* Linnaeus(=*capitis* DeGeer, *corporis* DeGeer, *vestimenti* Nitzsch), is an average-size member of the order, measuring from 2.00–3.25 mm. in length for the males and from 2.5–4.2 mm. in length for the females. It is a pale-colored species with dark markings along the sides.

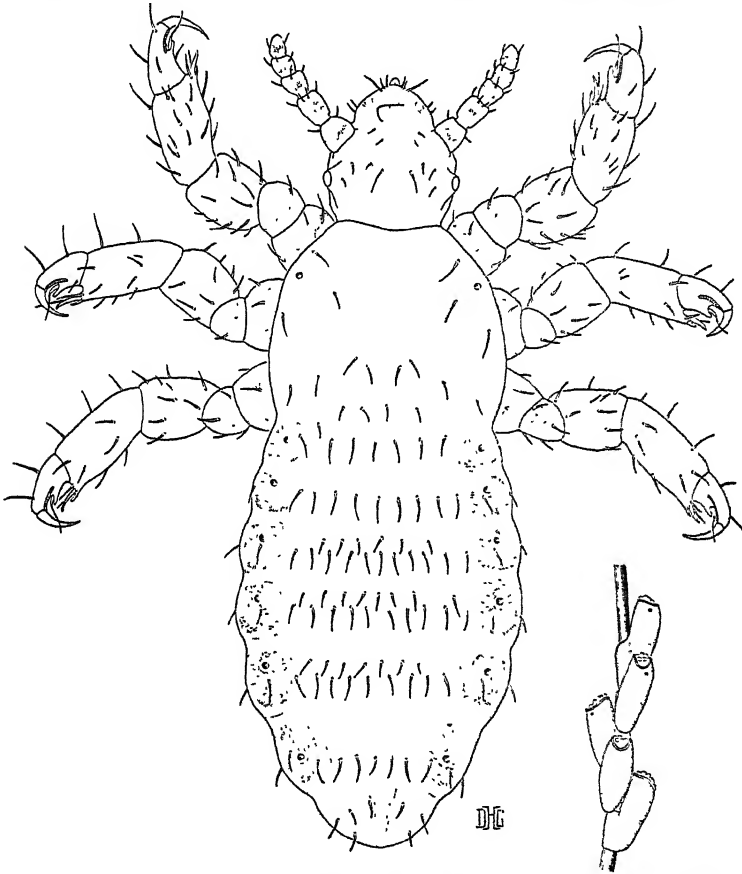


FIG. 75. The human louse, *Pediculus humanus* Linn. Adult female, and eggs attached to a hair. (From *A History of Entomology*.)

The eggs or nits are glued to hairs or to clothing and hatch in from 6 to 9 days. The young reach maturity in about 18 days. The entire life history is spent upon the body and in the clothing of the host. The lice not only cause severe itching and eczema-like eruptions of the skin, known as *pediculosis*, but they act as carriers and transmitters of such serious diseases as typhus fever, trench fever, and European relapsing fever. Perhaps only the honeybee and the silk-worm have played more important parts in entomological literature than this louse, which has long been discussed under two names, the body louse and the

head louse, but which is also known by no less than 18 synonymous scientific designations. Some form of the species has been found associated with primitive and civilized man throughout the world and possibly throughout the age of man.

The two other authentic biological species are, according to Ferris (1935), *Pediculus mjoberg* Ferris, infesting New World monkeys, and *Pediculus schäffi* Fahrenholz, on African chimpanzees.

Family HÆMATOPINIDÆ Enderlein 1904 (Hæm'a-to-pin'i-dæ, from the Greek αἷμα, αἷματος, blood, + πίνω, to drink; *i.e.*, blood drinkers, from the feeding upon blood).

A large genus of lice that infest certain ungulate mammals of the families EQUIDÆ, BOVIDÆ, CERVIDÆ, CAMELIDÆ, and SUIDÆ. A number of species infest domestic animals and may become quite injurious to them. In this family the most important genera are *Hoplopleura* Enderlein with 37 species; *Polyplax* Endl., 28 species; *Linognathus* Endl., 23 species; *Enderleinellus* Fahrenholz, 19 species; *Neohæmatopinus* Mjöberg, 17 species; and *Hæmatopinus* Leach, 11 species. Some of the most important species of the family are:

Sucking horse louse, *Hæmatopinus asini* (Linnæus); 2.5–3.5 mm. long, on horses, mules, asses, and zebras. Cosmopolitan.

Short-nosed ox louse, *Hæmatopinus eurysternus* (Nitzsch); 2–3 mm. long, on cattle. Cosmopolitan.

Hog louse, *Hæmatopinus suis* (Linn.); 3–6 mm. long, on swine. Cosmopolitan.

Spined rat louse, *Polyplax spinulosa* (Burmeister); 0.9–1.3 mm. long, on cattle. Cosmopolitan.

Old World mouse louse, *Polyplax serrata* (Burmeister); 0.8–1.4 mm. long, on rats and mice. Europe, Asia, and North America.

The sucking sheep louse, *Linognathus ovillus* (Neumann); 2.0–2.5 mm. long, on domestic sheep throughout their wide range over the world.

Sheep foot louse, *Linognathus pedalis* (Osborn); 2.2 mm. long, on the legs and feet of sheep. Cosmopolitan.

Sucking goat louse, *Linognathus stenopsis* (Burm.); 2 mm. long, on goats and sheep. Now almost cosmopolitan.

Sucking dog louse, *Linognathus setosus* (Olfers); 1.5–2.0 mm. long, on domestic dogs and on ferrets, foxes, coyotes, and rabbits. Practically cosmopolitan.

Long-nosed ox louse, *Linognathus vituli* (Linn.); 2.5 mm. long, on cattle. Cosmopolitan.

Capillate cattle louse, *Solenopotes capillatus* Enderlein; 1.25–1.75 mm. long, on domestic cattle. Europe and North America.

Members of the important genus *Hoplopleura* Endl. are confined to rodents belonging to the families including the rats and mice, squirrels, flying squirrels, and the coypus and tuco-tucos.

Species of the genus *Neohæmatopinus* Mjöberg infest generally squirrels and flying squirrels, but two live on the wood rats or pack rats.

The three species of *Hæmodipsus* Enderlein: *H. lyriocephalus* (Burmeister), *H. setoni* Ewing, and *H. ventricosus* (Denny), infest rabbits and hares. The last named is a pest of domestic rabbits in many parts of the world. It is able to transmit to man the disease known as tularæmia.

Family HÆMATOPINOIDIDÆ Ewing 1929 (Hæm'a-to-pin-oid'i-dæ, from the Greek αἷμα, blood, + πίνειν, drinker; blood drinkers).

A family erected for the genera *Hæmatopinoides* Osborn, which infests gophers in North America, and *Hamophthirus* Mjöberg, which is ectoparasitic on monkeys in Borneo.

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CHAPTER XXII

19. Order EPHEMERIDA¹ Leach 1817

(Eph'e-mer'i-da, from the Greek *ἐφήμερος*, living but a day, short-lived.) German, Eintagsfliegen, Hafte. French, Ephémères.

Mayflies, Dayflies, Ephemerids.

Small to medium-sized, soft-bodied, delicate, slender insects with inconspicuous, short, setiform antennæ. Vestigial mouth parts. Well-developed compound eyes and three ocelli. One or two pairs of fragile, many-veined wings held vertically over the back in repose, hind pair greatly reduced or wanting. Often apterous. Rather slender, weak legs; tarsi one- to five-segmented. Very long, filiform, multi-segmented cerci, and a similar median caudal filament. Simple or hemimetabolous metamorphosis. Subimagoes molting after emerging from nymphal skins. Naiads aquatic, similar in form to adults, but with abdominal tracheal gills and stronger rasping mouth parts.

The mayflies constitute a widely distributed and well-known group of insects which are descended from very ancient times. The primitive archaic mayfly, *Triplosoba pulchella* Brongniart 1893, the single representative of the order PROTOEPHEMEROIDEA Handlirsch 1908, is from the Carboniferous period. The earliest known fossil of a true mayfly, *Protoreisma* Sellards,² was taken in the Lower Permian rocks of Kansas. It differs from the present-day species in having both pairs of wings of nearly equal size and in being much larger. Remains of other related forms have been collected in the Lower Permian of Russia.³ Mayflies from the Jurassic period greatly resemble modern forms but are somewhat larger.

Adult mayflies are notably short-lived. Some species live but a few hours while others but a day or two and still others a week or more. The emergence of the adults often takes place at sunset, and, following a molt, a mating dance, and the laying of eggs, the fragile insects perish before dawn. The adult molt is

¹ The name of this order has so far proved to be the object of much difference of opinion, having been designated by no less than 40 different names. Among the most important designations were: ODONTOTA Latreille 1806, EPHEMERINA Burmeister 1829, ANISOPTERA Leach 1835, AGNATHA Meinert 1883, PLECTOPTERA Packard 1886, EPHEMEROPTERA Hæckel 1896, ARCHIPTERYGOTA Börner 1909. In recent works Brues and Melandner (1932) use PLECTOPTERA, Imms (1934) has adopted EPHEMEROPTERA, and Karny (1934) AGNATHA. The writer sees no reason why Leach's term, herein employed, should not be continued.

² Sellards (1907) erected the family PROTEREISMEPHEMERIDÆ in which he described a number of new genera and species, among them *Protoreisma minus* and *P. latum*.

³ These species according to Handlirsch (1926) are as follows: *Thnetus stuckenbergi* Handlirsch 1904, consists of a remnant of a wing collected in Kazan. *Phthartus netschajevi* Handlirsch 1904, a nymph in fair condition taken at Kargola, Orenburg, in 1894. *P. rossicus* Handlirsch 1904, a nymph in fair condition taken at Kargola, Orenburg. *Dyadentomum permense* Handlirsch 1904, the head and prothorax of a nymph taken at Dorf Kolpakovo in 1885.

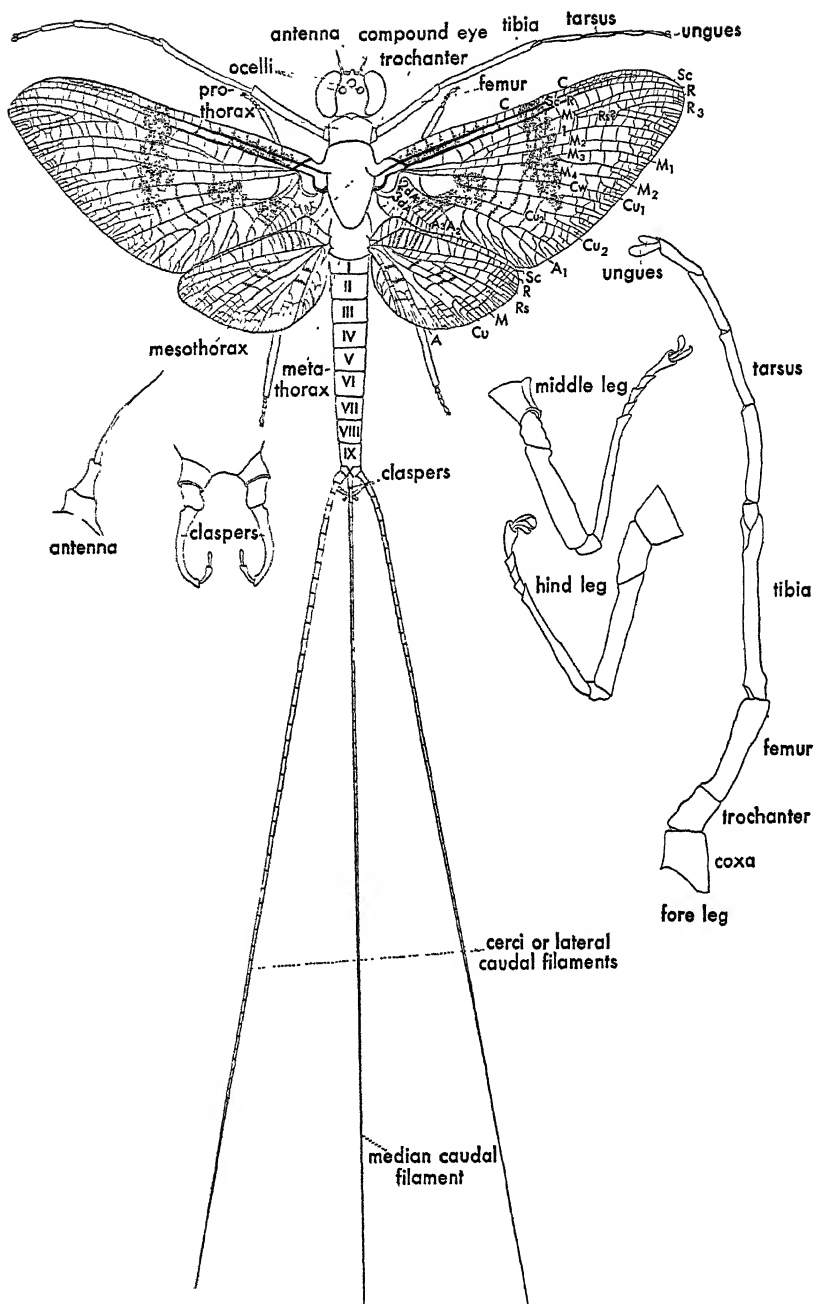


FIG. 76. The common European mayfly, *Ephemera vulgata* Linn.

an unusual phenomenon among winged insects. Upon emergence from the nymphal skin the winged adult seeks some suitable resting place where, within a few hours, a delicate skin or shroud is cast from the body and wings. The stage during the interval of inactivity prior to molting is called the subimago. But following it the true imago becomes a restless and remarkably active insect, and its characteristic dancing swarms are known to all observers of natural phenomena. In areas of fresh-water lakes and rivers in the warmer temperate regions and certain tropical regions, mayflies appear in swarms of incalculable numbers so as even to weigh down the shrubbery upon which they rest or to be cast up in great windrows along lake beaches after storms. Their mating flight or dance is most characteristic and consists chiefly in a rapid ascent followed by a slow descent oft repeated. They are attracted to lights and often nearly obscure them on warm late spring and early summer evenings during the period of emergence. A certain species of *Teloganodes* in Ceylon, has the abdomen faintly luminous. In the Great Lakes region and in other parts of North America they are often very abundant. It is stated by Cowan (1865) that they "usually make their appearance in the districts watered by the Seine and Marne [rivers in France] in the month of August; and in such countless myriads that the fishermen of these rivers believe they are showered down from heaven and accordingly call the living cloud of them *manna* — manna for fish, not men. Réaumur once saw them descend in this region so fast that the step on which he stood by the river's bank was covered by a layer four inches thick in a few minutes. He compares their falling to that of snow with the largest flakes." According to Sharp (1895), "D'Albertis observed *Palingenia papuana*¹ in countless myriads on the Fly River in New Guinea: 'For miles the surface of the river, from side to side, was white with them as they hung over it on gauzy wings; at certain moments, obeying some mysterious signal, they would rise in the air and then sink down anew like a fall of snow.'" Tillyard (1926) in commenting on this remarkable species states that "not a single imago has ever been observed, and it is believed that this species mates and dies in the subimaginal stage." J. A. Scopoli in 1763 records mayflies so abundant in Carniola that in one place in June they were gathered by the cartload and used for fertilizer.

The eggs are quite variable, but nearly all are extremely small, white, green, light brown, and probably other colors, somewhat sculptured, viscid, and have some means of anchorage. The latter usually consists of knobs and filaments which cling to vegetative growth or debris in the water. Certain eggs also have prominent micropylar structures (Fig. 77). The eggs are usually extruded directly into the water and are washed off in masses or loosely on the surface of the water, or the female may descend, like certain other aquatic insects, into the water to lay her eggs under stones. Great numbers are laid, each female having the capacity to produce from a few hundred to as many as 4,000. The eggs hatch in from 7 to 14 days, or even months may be required. In rare cases females are viviparous and give rise to minute active naiads. The newly born young of all forms have no gills and must therefore absorb oxygen through

¹ The great Papuan mayfly, *Plethogenesia papuana* (Eaton).

the skin. With the first molt the gills arise, a pair at a time in successive molts. The young or naiads normally hide on the bottoms of streams and lakes under stones, debris, and aquatic vegetation. Occasionally they may be seen darting across open spaces or clinging to stones and other supports. The thin flat species

cling tightly to rocks where the current is swift, and other forms are found in quiet waters where they move freely among the water flora. The naiads of still other species are fossorial and burrow in the mud on the bottoms or in the banks of streams. They are capable of very rapid movement in water, swimming by means of the fringed caudal appendages and the gills.

According to Morgan (1913), "Mayflies are almost entirely herbivorous. Their food consists chiefly of fragments of higher plant tissue, algæ and diatoms." Nymphs of two species are reported injurious to structural timbers below water in Thailand (*Rev. Appld. Ent. Ser. A*, 26: 149, 1938). Certain amounts of animal food in the form of other mayfly naiads and aquatic insects are eaten by some species. The young of some species are very interesting aquarium animals that furnish ample opportunity for many delightful observations, providing they are supplied with the necessary plant life, aëration, and the exclusion of predators. The complete life history of the naiads is rather difficult to study and that of but few species is accurately known. Naiadal development is usually rather slow, requiring from 1 to 3 years. During this period the

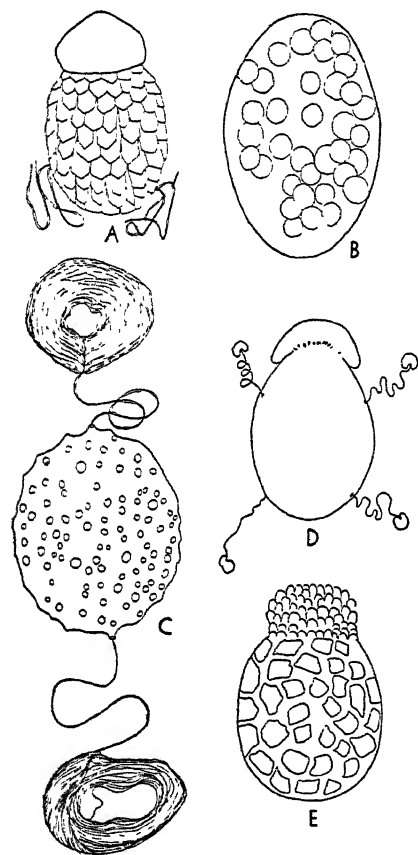


FIG. 77. Eggs of mayflies. A, *Tricorythodes allectus* (Needham); B, *Isonychia albomanicata* (Needham); C, *Stenonema interpunctata* (Say); D, *Ephemerella rotunda* Morgan; E, *Ephoron album* (Say). (All after Morgan, 1913.)

naiad may undergo as many as 24 molts. However, in certain species development is rapid. The life cycle of *Callibaetis* is completed, according to Needham and Lloyd (1930), in less than 6 weeks. If a single female lays 1,000 eggs and all develop and reproduce through a single season the members of the fourth brood would number 125 billions. Of course such a phenomenal increase is not possible, but these figures give some idea of the reproductive

<i>Naiad</i>	<i>Adult</i>
Elongate and campodeiform.	Elongate and somewhat flattened or cylindrical.
Head large with two compound eyes and three ocelli.	Head small, compound eyes always present, larger and often divided in the male, the front portion being raised or pillared and known as turban-eyed. With three ocelli.
Antennæ usually quite long, filiform and many segmented.	Antennæ usually short, composed of two basal segments and an indistinctly jointed apical portion.
Mouth parts well developed, with labrum, strong mandibles, three-segmented maxillary palpi, quadrifid labium, three-segmented labial palpi, and conspicuous maxillulæ associated with the hypopharynx. Mandibles of a very primitive type.	Mouth parts aborted or at most very weakly developed; mandibles vestigial or absent, maxillæ very small, but with palpi present.
Thoracic segments large, prothorax narrowest.	Thoracic segments well developed with the mesothorax much larger than the other segments.
Legs shorter and stouter than in the adults, one-segmented tarsi with single claw.	Legs variable, fore pair greatly elongated in some males to aid mating, one- to five-segmented tarsi (usually four to five) with two simple or bifid claws.
Apterous or with wing pads.	Apterous or generally with two unequal pairs of many-veined, fragile wings, of which the fore pair is much the larger and the hind pair often very small or even wanting.
Abdomen obviously 10-segmented, the 11th segment assuming the form of a many-segmented median filament as long as or shorter than the cerci. The median filament may not appear in the first stage young.	Abdomen obviously 10-segmented, the 11th segment in the form of a reduced tergum or a greatly elongated, multi-segmented appendage similar in form and length to the cerci. The male genitalia consist of a pair of simple incurved claspers and two penes, each with a separate opening. The oviducts of the female open between sternites 7 and 8.
Cerci rather short or long and slender, many-segmented and often with conspicuous fringes.	Cerci long, filiform, multi-segmented, and shorter or longer than the body.
Respiration by external gills upon some or all of the first seven abdominal segments extending from the dorsum or sides. Gills variable in size and form, but often leaf-like in appearance. No other insects have gills so situated.	Respiration spiracular through two pairs of thoracic and eight pairs of abdominal spiracles.

potentialities of mayflies and show why the naiads constitute one of the most important and stable foods of fresh-water fishes, aquatic insects, and other small animals. Their reproductive capacity must be exceedingly great to enable such helpless creatures to survive at all. However, Tillyard (1926) states that certain species in New Zealand are threatened with extermination by the introduction of the European brown trout and the American rainbow trout.

External anatomy. — Some of the most striking anatomical features of the adults have already been given. The compound eyes are largest in the males,

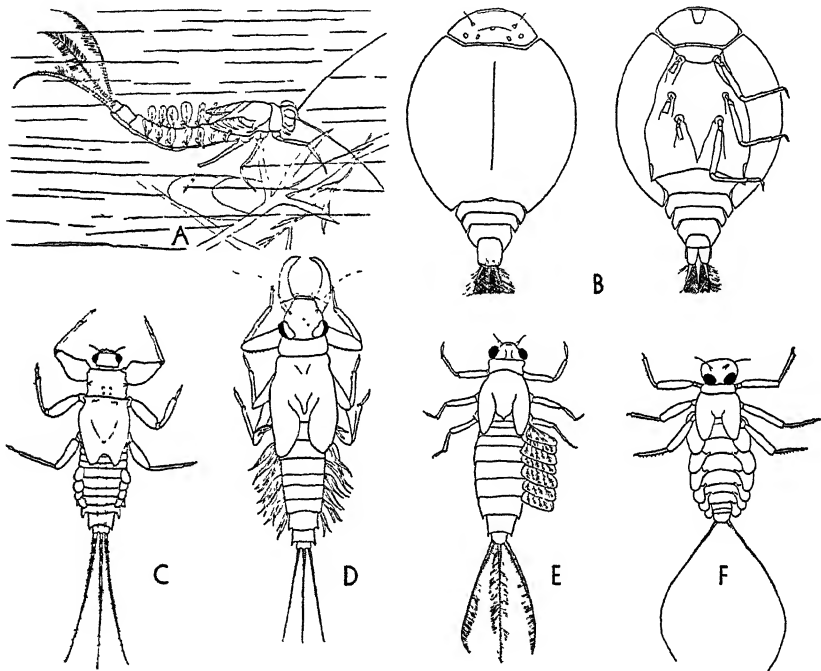


FIG. 78. Naiads of mayflies. A, *Callibaetis fluctuans* (Walsh); B, *Prosopistoma foliaceum* Fourcroy, dorsal and ventral aspects; C, *Ephemerella grandis* Eaton; D, *Paraleptophelbia packii* (Needham); E, *Siphonurus occidentalis* Eaton; F, *Iron longimanus* (Eaton) (A after Morgan, 1913; B after Eaton, 1883-8; C-F after Needham, 1927.)

and in certain genera the facets of the upper portions of the eyes in both sexes are larger than those of the lower. There is a division of the eyes in *Cloëon*, which, the upper portions being elevated upon tubercles, are said to be pillared or turban-eyed. The three ocelli are between the compound eyes. The mouth parts of the adults are aborted or weakly developed, indicating that the mature forms do not take nourishment. The pro- and metathorax are small, whereas the mesothorax is large and well developed to motivate the insect in its brief

but continuous flight. The wings are somewhat triangular in shape, the fore pair greatly developed and the hind pair very small or even absent. The venation is of a primitive type, as indicated by the accompanying drawings (Figs. 76, 80). One of the important features of the venation is the presence of the intercalary veins which have no basal connections but are supported by numerous cross veins. The legs are variable, being well developed in some species and atrophied in others. In the males of many species the fore pair is much longer than the others and may be extended forward when at rest, appearing not unlike antennæ. The most important anatomical features of the naiads and adults may be tabulated as shown on page 215.

Internal anatomy. — The internal anatomy of mayflies is only imperfectly known in spite of the fact that the great naturalist Jan Swammerdam rather carefully worked out the internal anatomy as early as 1666. An unusual organ, not found in other insects, is a small, wholly chitinous body located in the head, just below and posterior to the ocelli. It lies between two tracheal tubes that connect on each side with the main tracheal trunks extending into the head. It is called Palmen's organ and occurs in the naiads and adults, and, while thought to have something to do with orientation in the immature forms, its function in the imago is unknown. The more important known features are:

<i>Naiad</i>	<i>Adult</i>
Alimentary canal for normal processes of digestion.	Alimentary canal modified for the storage of air to aid in flight.
Esophagus wide.	Esophagus narrow tube with dilator muscles to regulate the air flow from mouth to stomach.
Stomach with normal epithelial and muscular coats.	Stomach an air storage sac.
Malpighian tubules numerous, may be more than 100.	Malpighian tubules 40 in number.
	Fore part of the hind intestine with valves to check the air flow from the stomach.
	Sexual organs primitive with no accessory glands, gonoducts paired in both sexes, each with separate opening.

The order EPHEMERIDA is a comparatively small one, consisting of about 150 genera and some 1,270 species distributed in the Palæarctic, Nearctic, Neotropical, Ethiopian, and Indo-Australian regions. Probably less than half of the species of the world are described to date.

KEY TO SUPERFAMILIES

(After Ulmer, 1933)

1. Hind tarsi with four or less movable segments; if a fifth is present it is fused with tibia 2
 Hind tarsi with five free segments. 3
2. M_{1+2} and Cu_1 of fore wing diverging strongly at base . EPHEMEROIDEA
 M_{1+2} and Cu_1 of fore wing parallel at their bases BÆTOIDEA p. 221
3. M_{1+2} of fore wing parallel at their bases
 (HEPTAGENEOIDEA) ECDYUROIDEA p. 223

Superfamily EPHEMEROIDEA Ulmer 1920

KEY TO FAMILIES — ADULTS

1. Sc of fore wing hidden in a fold and visible only at base; wings dull and translucent; legs of female short and weak; two caudal filaments
 PALINGENIIDÆ
 Sc of fore wing visible throughout its length 2
2. Wings translucent in male, opaque in female; hind margins of wings without intercalary veins; legs weak, forelegs sometimes long in male POLYMITARCIDÆ p. 220
 Wings transparent and glistening; numerous intercalary veins at wing margins, especially of posterior wings; legs normal 3
3. Cu_1 of fore wing simple, connected with margin by veinlets; fork of R_2 and R_4 in hind wing longer than its stem EPHEMERIDÆ p. 220
 Cu_1 of fore wing forked, not connected with margin by veinlets; fork of R_2 and R_4 in hind wing not longer than its stem POTAMANTHIDÆ p. 220

Family PALINGENIIDÆ Klapálek 1909 (Pal'in-gen-i'i-dæ, from the Greek *παλιγγενεσία*, a new birth; in allusion to its annual swarming).

The naiads have large, protruding, toothed mandibles, fossorial fore tibiae, and three caudal appendages of which the median is shortest.

In the adults both pairs of wings have numerous longitudinal and cross veins. The legs of the female are short and feeble or very much reduced. The male claspers are four-segmented: the first segment very short, the second incurved and longer than the combined length of all the others.

Among the more important world genera are: *Palingenia* Eaton (Palæarctic), *Anagenesia* Eaton (Palæarctic), and *Plethogenesia* Ulmer (Indo-Malaysian).

The largest and most beautiful European species is the long-tailed mayfly, *Palingenia longicauda* Olivier, a brownish species 25–38 mm. long with two very long cerci and a very short median anal filament. It often occurs in large numbers and appears to be the species studied by the eminent Dutch entomologist, Jan Swammerdam, along the River Rhine at Culenborg, Holland, beginning in 1661. His famous drawing of the partly dissected naiad in his *Bybel der Natuure* in 1738 is reproduced in Fig. 79. The species was described by the French entomologist Olivier in 1791.

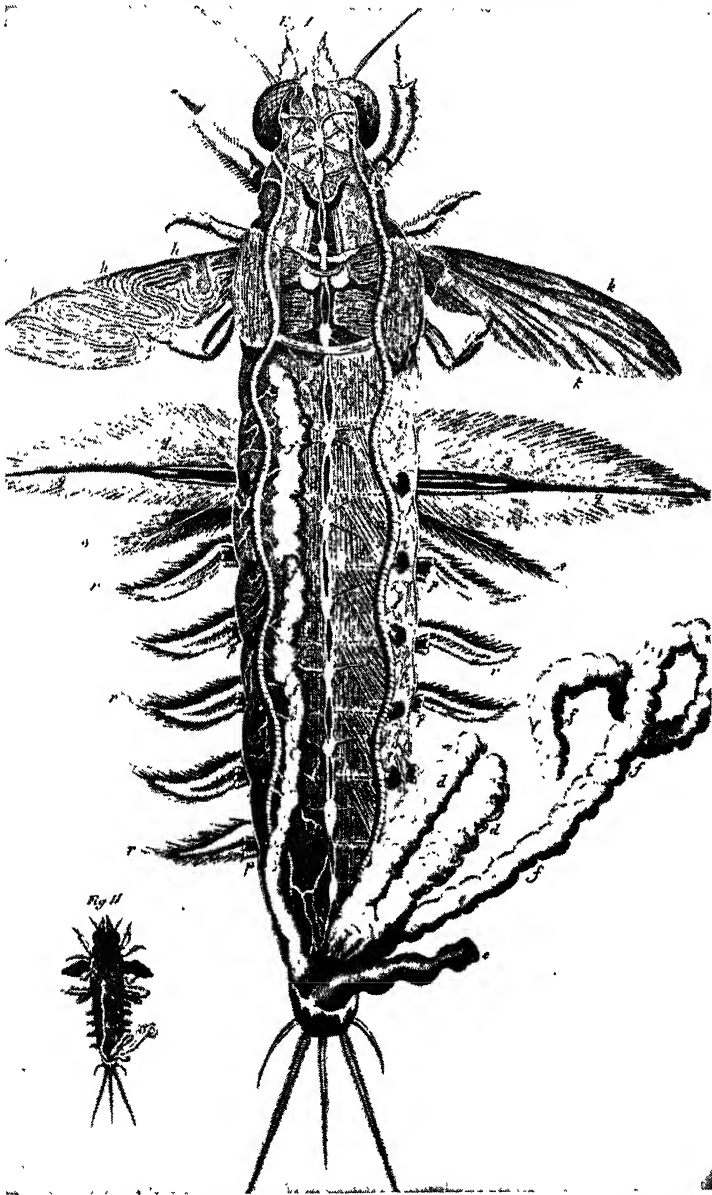


FIG. 79. A famous historical drawing showing the internal anatomy of the naiad of the long-tailed mayfly, *Palingenia longicauda* Oliver, by Swammerdam as it appeared in *Bybel der Natuur* in 1738. It was made with the aid of a small simple lens. This large mayfly is common to the lower portions of the Rhine and neighboring rivers in Europe.

Family POLYMITARCIDÆ Klapálek 1909 (Pol'y-mi-tar'ci-dæ, from the Greek πολύμιτος, consisting of many threads, + ἄρκυς, net; referring to the numerous fine net-like veins).

Naiads with long tusk-like mandibles and three equal caudal filaments. They occasionally dig into mud.

The male claspers are four-segmented, incurved; the first segment about half as long as the second, the two apical segments very small.

The important genera are: *Povilla* Navás (Ethiopian), *Euthyplocia* Eaton or *Exeuthyplocia* Lestage (Ethiopian), *Campsurus* Eaton (Neotropical), and *Polymitarcys* Eaton (cosmopolitan).

The virgin mayfly, *Polymitarcys virgo* (Olivier) 1791, is one of the commonest European species. The naiads are pale yellowish. The fore and hind legs are strong and the middle legs reduced. The first pair of gills is exceedingly small while the remaining six pairs are double, leaf-like, with fringed expansions curved over the dorsum. The three long anal filaments are fringed. The adults are light yellow marked with brown, vary from 10–18 mm. in length, and have two caudal filaments and small hind wings. They often appear in great swarms during August and September and may darken the lights along the rivers.

Family EPHEMERIDÆ Klapálek 1909 (Eph'e-mer'i-dæ, from the Greek ἐφήμερος, living but a day; from the brief life of the adult).

The naiads have elongated, somewhat cylindrical bodies, tapering towards both ends. They have long tusk-like mandibles that curve outwards, rather long fringed antennæ, and three equal anal filaments. Their legs are strong, enabling them to dig into the mud. They inhabit only muddy bottoms or muddy water.

The adults have rather small hind wings and two or three very long caudal filaments. The male claspers are four-segmented, the second segment strongly incurved and much longer than any of the others.

The commonest genera are *Hexagenia* Walsh (Nearctic, Neotropical, Ethiopian), *Ephemera* Linn. (Holarctic, Indo-Australian), *Eatonica* Navás (Ethiopian), and *Pentagenia* Walsh (Nearctic).

The common mayfly, *Ephemera vulgata* Linnæus 1746, is often very abundant in many parts of Europe during the summer from May into August. It is whitish with dark markings on the body and wings and measures from 16–24 mm. in length.

Family POTAMANTHIDÆ Klapálek 1909 (Pot'am-an'thi-dæ, from the Greek ποταμός, a river, + ἄνθος, flower; from the flower-like gills?).

The naiads have short, tusk-like mandibles, long, bifid, fringed gills, and three equal caudal filaments. The legs are crab-like, and the tibia is prolonged into a flat spine which overlaps the base of the tarsus. They live upon silt-covered stones on muddy bottoms.

The adult male has forelegs as long as the body, the claws of which are blunt,

The important genera are: *Potamanthus* Pictet (Holarctic), *Rhoënanthus* Eaton (Palæarctic, Indo-Malaysian), and *Potamanthodes* Ulmer (Indo-Malaysian).

KEY TO FAMILIES

1. Sc of fore wing entirely visible and separated from R 2
Sc of fore wing not visible, or visible at base only, fused with R or absent;
wings milky or grayish with simplified venation, cross veins limited to anterior part of fore wings OLIGONEURIELLIDÆ
2. MA in fore wing clearly forked 3
MA in fore wing not forked; wings transparent; fore wings with few cross veins; hind wings small and narrow or absent BÆTIDÆ
3. Wings clear, with many cross veins; hind wings usually present . . . 4
Wings milky, fringed on hind margin, often with but few cross veins; hind wings absent (sometimes present in subimago); small species CÆNIDÆ p. 222
4. Cu₂ in fore wing separate from Cu₁ at base but lying close to 1A; no free intercalary veins between M and Cu . . . LEPTOPHLEBIIDÆ p. 222
Cu₂ in fore wing close to Cu₁ at base but widely separate from 1A; usually two free intercalary veins between M and Cu EPHEMERELLIDÆ p. 223

The naiads are elongated with rather long antennæ and legs, leaf-like gills, and three caudal fringed filaments, the median being shorter than the cerci. They inhabit waterfalls, cataracts, and slow currents or open waters and min-

gle also with the mud dwellers on the one hand and the cascade dwellers on the other and may be found on or among aquatic plants in still pools.

The adults have comparatively few cross veins, and the hind wings are very greatly reduced or wanting. There are two caudal filaments. The males of some *Bætis*,¹ *Cloëon*, and *Centroptilum* have turban eyes. The claspers are four-segmented although some are so poorly jointed as to appear but three-segmented. The second segment is slender and often about as long as the first and may be fused with the third which is much the longest and frequently incurved. The apical segment is very small and not always distinctly separated.

This is also a large and cosmopolitan family represented by the following important genera: *Bætis* Leach (widespread — the naiads often living in waterfalls), *Cloëon* Leach (cosmopolitan), *Centroptilum* Eaton (Holarctic, Ethiopian), *Callibætis* Eaton (American), and *Procloëon* Bengtsson (Palæarctic).

Bætis posticatus (Say) is a common mayfly in the upper Mississippi River valley. The small black and greenish-white adults, which have hyaline wings and are but 8–19 mm. long, swarm early in May along rapid streams. Following mating, the females alight on stones, crawl under the surface of the water, attach gelatinous masses, containing from 80 to 300 eggs, to the surface of the rocks, and then perish. The eggs hatch in a month. The naiads molt about 27 times and finally emerge as adults in October. These mate, lay eggs, and give rise to another brood which emerges the following August. Thus there are three broods in two years.

Family CÆNIDÆ² Klapálek 1909 (Cæ'ni-dæ, from the Greek *καινός*, novel, new, strange; in reference to the peculiar naiads).

The naiads are peculiar in having the second pair of gills very large and elytrum-like, covering the succeeding pairs. The three caudal filaments are nearly equal in length. They live under a variety of conditions, many of them inhabiting sand or mud bottoms.

The adults have very few cross veins and no hind wings, three caudal filaments, and their male claspers are horn-shaped and one-segmented.

The family is quite a large one with a wide distribution. The most important genera are *Cænis* Stephens (cosmopolitan), *Tricoryphodes* Ulmer (American), *Leptohyphes* Eaton (South American), *Leptohyphodes* Ulmer (Neotropical), *Tricorythus* Eaton (Ethiopian), *Brachycercus* Curtis (Palæarctic).

Family LEPTOPHLEBIIDÆ Klapálek 1909 (Lep'to-phleb-i'i-dæ, from the Greek *λεπτός*, fine, small, + *φλέβιον*, veinlet; referring to the slender veins).

The naiads are elongated, with fairly long antennæ and three equal caudal filaments as long as or almost as long as the body and with long slender leaf-like or string-like gills.

¹ This appears to be the correct form of this word since it is so printed in connection with the brief description of the genus by Leach. Continuing on the same page (p. 137), however, the spelling is changed to *Bæltis* when used with the species *bioculatus*, and is *Bætis* in the index (p. 163). The first use has precedence (Leach, W. E., "Entomology," in Brewster, *Edinburgh Encyclopedia*, vol. 9, pp. 137, 163, 1815).

² Also BRACHYCERCIDÆ Lestage 1917 (?).

Adults with many fine wing veins, very small hind wings, and three very long equal caudal filaments. The male claspers are three- or four-segmented, the basal segment very broad, the second long and incurved, the third short, and the fourth about half as long as the third. When but three segments are present, the base is wider and as long as or longer than the second. The third is only slightly shorter than the second.

This is a large and widely distributed family of which the most important genera are: *Choroterpes* Eaton (Holarctic), *Thraululus* Eaton (Holarctic, Indo-Malaysian), *Atalophlebia* Eaton (Neotropical, Indo-Malaysian), *Habrophlebia* Eaton (Holarctic), *Leptophlebia* Westwood (Holarctic), *Adenophlebia* Eaton (Ethiopian), *Paraleptophlebia* Lestage (Palæarctic), and *Habroleptoides* Schoenemund (Palæarctic).

Family EPHEMERELLIDÆ Klapálek 1909 (Eph'e-mer-ell'i-dæ, from the Greek ἐφήμερος, living but a day, + the Latin diminutive *ella*).

The naiads are elongated or rather short and almost crab-like. They have rather long antennæ and three equal, nearly naked or fringed caudal filaments. The gills are flat and half or a third the width of the abdomen.

They cling to stones, often to the undersides, in swift waters. In some the venter of the abdomen forms a sucking disk. They are often strikingly and cryptically colored.

The adults have very small hind wings and three caudal filaments. The male claspers are three-segmented, the basal and apical segments short and the middle segment very long and incurved.

The most important genera are *Ephemerella* Walsh (Holarctic), *Drunella* Needham (Nearctic), *Teloganodes* Eaton (Indo-Australian), and *Torleya* Lestage (Palæarctic).

Superfamily ECDYUROIDEA (HEPTAGENEOIDEA Ulmer 1920)

KEY TO FAMILIES

1. Cu_1 , Cu_2 and 1A of fore wing somewhat parallel and equal in length; hind wing almost circular, with many long intercalary veins; pronotum very small **BÆTISCIDÆ** p. 225
 Cu_1 and Cu_2 of fore wing close at base but strongly divergent distally; Cu_2 much shorter and more strongly curved than Cu_1 ; hind wing oval 2
2. Cu_1 of fore wing with more or less oblique, sinuous veinlets passing to wing margin (SIPHLURIDÆ) **SIPHLONURIDÆ** p. 224
 Cu_1 of fore wing without such veinlets; two or four parallel unattached intercalary veins in cubital area 3
3. One pair of intercalary veins between Cu_1 and Cu_2 , sometimes vestiges of a second pair lying near Cu_2 ; two or three caudal filaments **AMETROPODIDÆ** p. 224
Two pairs of intercalary veins between Cu_1 and Cu_2 , the larger pair near Cu_2 ; two caudal filaments (HEPTAGENIIDÆ) **ECDYURIDÆ** p. 224

N.B. Standing apart from the above families but related is the peculiar (subimago and naiads only are known) . . . PROSOPISTOMATIDÆ p. 225

Family ECDYURIDÆ Klapálek 1909 (**HEPTAGENIIDÆ** Bengtsson 1913)¹
(Ec'dy-ur'i-dæ, from the Greek ἐκδύω, to put off, + οὐρά, tail; in reference to the abortion of the median caudal filament).

The naiads have body and appendages depressed, the head large, and the gills flat and leaf-like. The legs are crab-like and there are two or three (equal) long, almost naked caudal filaments. They live in rapid waters, clinging to the surface of stones and other objects, along wave-washed lake shores and the margins of gently flowing streams.

The wings are many veined and the hind wings are variable in size, often being very greatly reduced. There are two caudal filaments. The male claspers are four-segmented, the basal segment short, the second very long and slightly incurved, the apical segments small with the third longer than the fourth.

This family is represented by a large number of species. The important genera are: *Ecdyurus* Eaton (Holarctic), *Heptagenia* Walsh (Holarctic), *Epeorus* Eaton (Holarctic), *Iron* Eaton (Nearctic), *Rhithrogena* Eaton (Holarctic), and *Atopopus* Eaton (Indo-Australian).

Epeorus assimilis Eaton 1885 is one of the commonest species in Europe during July and August. It is brown and black and varies from 12-14 mm. in length.

Family AMETROPODIDÆ Bengtsson 1913 (Am'e-tro-pod'i-dæ, from the Greek ἀμετρος, immense, + πούς, ποδός, foot; from the unusual development of the fore tarsi).

The adults have many-veined wings and three caudal filaments. The male claspers are four-segmented and slightly incurved, the basal segment quite long, the second segment longest, and the two apical segments quite short.

This is a small family represented by only two important genera, *Ametropus* Albard and *Metropus* Eaton, both Palearctic.

Family SIPHLONURIDÆ Klapálek 1909 (Si'phlon-ur'i-dæ, from the Greek σιφλός, maimed, defective, + οὐρά, tail; in allusion to the short median caudal filament).

The naiads have small heads, large, flat gills, three fringed caudal filaments which are equal or have the median slightly shorter, and small legs. They live in running water and may be taken in cataracts and waterfalls.

The adults have many-veined wings and well-developed, though small, hind wings, and two caudal filaments. The male claspers are four-segmented, the basal segment wide, the second longest and slightly incurved, and the two apical segments small.

This is a rather large family well distributed throughout the world. The

¹ ECDYONURIDÆ and *Ecdyonurus* are misspellings of ECDYURIDÆ and *Ecdyurus* and should be replaced by the latter. (See Eaton, 1883-7, p. 49.)

most important genera are: *Siphonurus*¹ Eaton (Holarctic), *Ameletus* Eaton (Holarctic, Australian), *Chirotonetes* Eaton (Nearctic), *Siphonisca* Needham (Nearctic), *Siphurella* Bengtsson (Palæarctic), *Isonychia* Eaton (Holarctic), *Oniscigaster* McLachlan (Indo-Australian), and *Coloburiscus* Eaton (Austrian).

Ameletus ornatus Eaton of New Zealand is remarkable in that the nymphs crawl out of the water on the damp rocks near or in the spray of waterfalls and cascades and jump back into the water when disturbed. *A. percitus* Eaton, another large New Zealand species, is carnivorous.

Family BÆTISCIDÆ Ulmer 1920 (Bæ-tis'ci-dæ, see BÆTIDÆ for derivation).

The eastern American species, *Bætisca obesa* Walsh, will serve as a representative of this family. The naiad is peculiar and is described by Needham as having a huge four-spined carapace formed by a backward prolongation of the thoracic notum which meets a conspicuous pyramidal elevation on the middle of the abdomen to enclose a respiratory chamber within which the gills are included.

It is a rare species thought to inhabit the rapid waters of larger rivers.

The male subimago has partly clouded wings whereas the imago has hyaline wings.

Family PROSOPISTOMATIDÆ Lestage 1919 (Pro'so-pis'to-mat'i-dæ, from the Greek πρόσωπον, face, + στόμα, στόματος, mouth; from the mouth being concealed by the large mentum or underlip).

The naiads are peculiarly flat, oval, and disk-like. The mouth is hidden by the mentum, and the gills are concealed by a large elytrum-like extension which covers most of the abdomen. There are three short, equal, fringed caudal filaments. They appear to be well adapted to clinging to stones in swift running water.

The subimago appears to be the only adult form known. It has very simple wings without cross veins.

This is a very small family with only a few known species belonging to the genus *Prosopistoma* Latr. which occur in the rivers of continental Europe and Madagascar.

KEY TO FAMILIES—NAIADS

(See Fig. 78)

1. Gills hidden beneath a large shield-like prolongation of the thorax posteriorly which covers most of the abdomen . PROSOPISTOMATIDÆ
Gills visible at their insertion above or on the sides of the abdomen 2
2. Mandibles usually very long and extending anteriorly; six or seven pairs of plumose gills, the first sometimes much reduced; legs stout 3
Mandibles very short, not extending anteriorly; gills not plumose;
legs slender 6

¹ Originally spelled *Siphonurus* by Eaton (1868) and subsequently changed to *Siphururus* by the same writer in 1871, 1883-1888. The former name stands.

3. Mandibles extending but slightly beyond the head; gills extended laterally away from the abdomen **POTAMANTHIDÆ** p. 220
Mandibles very large and extending anteriorly far beyond the head; gills extended dorsally over the abdomen 4
4. Front of head with two tubercles; mandibles curved outwards at tips; antennæ with long lateral cilia **EPHEMERIDÆ** p. 220
Front of head without tubercles; mandibles curved downwards at tips; antennæ devoid of or with very short lateral cilia 5
5. Body short and stout with six pairs of like gills; caudal filaments short, the median shortest **PALINGENIIDÆ** p. 218
Body long and slender with seven pairs of gills, the first pair much reduced in size; caudal filaments long and of equal length **POLYMITARCIDÆ** p. 220
6. Body distinctly flattened; the head spherical or somewhat transverse with the eyes dorsad 7
Body somewhat cylindrical or very slightly depressed dorsally, head transverse with the eyes laterad 8
7. Submaxillary gills present; first pair of abdominal gills extending from the venter of the first segment, the succeeding six pairs extending from the sides of the abdomen; caudal filaments shorter than the body **OLIGONEURIELLIDÆ** p. 221
Submaxillary gills absent; abdominal gills uniformly extending from the sides of the abdomen; caudal filaments as long as or longer than the body **ECDYURIIDÆ** p. 224
8. Cerci or lateral caudal filaments fringed on both margins 9
Cerci fringed only on the inner margin 11
9. Seven pairs of gills inserted laterally at the sides of the abdomen; all are filamentous or the first pair is much reduced and forked and the others leaf-like **LEPTOPHLEBIIDÆ** p. 222
Five or six pairs of gills inserted dorsally at the sides of the abdomen 10
10. Six pairs of gills, the first very small, the second greatly enlarged and elytrum-like and covering the remaining pairs, which are leaf-like and fringed with hairs **CÆNIDÆ** p. 222
Five pairs of leaf-like gills, the last or the last two pairs invisible **EPHEMERELLIDÆ** p. 223
11. Body cylindrical; head inclined downwards; posterior margins of abdominal segments not produced **BÆTIDÆ** p. 221
Body somewhat flattened; head horizontal or normal; hind lateral margins of the abdominal segments produced into a tooth-like projection 12
12. Claws not longer than the tibiæ **SIPHONURIDÆ** p. 224
Claws of the middle and hind legs stout, as long as the tibiæ; those of the front legs bifid at tips **AMETROPODIDÆ** p. 224

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CHAPTER XXIII

20. Order ODONATA Fabricius 1793¹

(O-don'a-ta, from the Greek *ὄδους*, *ὀδόντος*, a tooth.)² German, Libellen, Wasserjungfern, Gleichflügler, and Ungleichflügler. French, Libellulides, Demoiselles.

Damselflies, Dragonflies, Devil's Darning Needles, Snakedoctors, Mosquito Hawks.

Medium-sized to large, slender, slow or swift-flying, predacious insects with hemimetabolous or simple metamorphosis, biting mouth parts, mobile head, very large lateral compound eyes and three ocelli, strong mandibles, one-segmented maxillary palpi, two-segmented labial palpi; enlarged thorax; short, spiny legs, three-segmented tarsi; two pairs of similar long, narrow, net-veined wings which are held straight from the sides or over the back in repose; long, slender, cylindrical or flattened abdomen, male copulatory organs on the second and third sternites, nymphs or naiads aquatic; with greatly developed raptorial labium or mask; with or without exterior caudal gills.

The damselflies and dragonflies are almost as well known as are the butterflies and moths and are among the most interesting and fascinating of all insects. Who has not viewed with wonder and admiration the swift hawking flight of the dragonflies and felt amazement at their skill and poise in turning, darting, balancing, alighting, and taking off? No other animal or mechanism can match their versatility in the air. There is a remarkable similarity between the lines of modern airplanes and those of dragonflies, as if man had attempted to reincarnate these insects in powered metal. The odonates are variable in size but rather stable in form. The largest living dragonfly appears to be the Central and South American *Megaloprepus caerulatus* (Drury) which has a wing expanse of $7\frac{1}{2}$ in., whereas the smallest damselflies of the Australian genera *Agriocnemis* and *Austrocnemis* have a wing expanse of slightly less than 1 in. The damselflies are somewhat fragile in appearance because of their very slender bodies and rather slow, sculling flight. The colors are plain and even somber in some of the temperate-region species while others are beautifully striped, spotted, and banded with bright colors and many are blue, green, yellow, red, and other hues. Tropical and subtropical species may be arrayed in brilliant metallic shades equalled only by those of butterflies in the same regions. Many forms are covered with a whitish bloom that softens the brilliance of their

¹ These insects have also been grouped under many other names of which the following are the most important: CRYPTODONTIA Latreille 1802, LIBELLULIDES Leach 1815, LIBELLULINA Newman 1834, PARANEUROPTERA Shipley 1904.

² Referring to the conspicuously toothed maxillæ of the mouth parts which are more pronounced in this than in any other order of insects (Mickel 1934).

displays. The sexes are of the same general colors or the female may be duller or even more brightly adorned, and in rare cases there may be two color phases within a single species. The wings are devoid of scales and hairs except in a very few instances and, while they are usually hyaline, they may be clouded with blackish, brownish, or brilliant colors.

Remnants of extinct ancestral forms of the dragonflies, known as PROTO-
DONATA Handlirsch,¹ have been found in the coal measures of Commen-
try

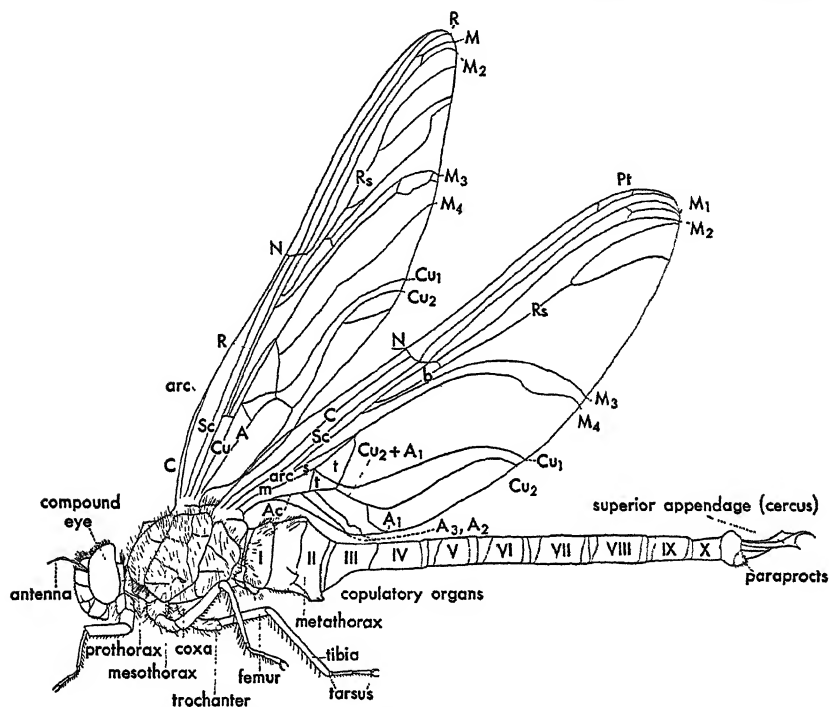


FIG. 80. The large dragonfly, *Aeschna multicolor* Hagen, with important parts named.

near St. Etienne, France. True dragonflies did not appear until the Lower Permian. These differ from the present living forms in lacking the subnodus and the discoidal cell and in having few antenodals, a very short subcosta ending at the nodus, and a large number of other characters which have made it necessary to place them in the separate suborder, PROTOZYGOPTERA².

¹ The giant *Meganeura monyi* Brongniart 1884 and *M. brongniarti* Handlirsch 1908, of Commen-
try, France, had wings nearly 12 in. long and a wing expanse of about 27 in. *Paralogus*
aeschnoides Scudder 1893, from Rhode Island and Pennsylvania, had wings only about 2½ in.
long.

² Probably the most interesting member of this ancient order is *Kennedya mirabilis* Till-
yard 1925, taken from the Lower Permian of Kansas.

Great numbers of Post-Permian fossil dragonflies have been discovered in many parts of the world and are admirably treated by Handlirsch (1908).

Although the immature stages are strictly aquatic the adults, especially of the strong-flying dragonflies, are often seen great distances from water.

The eggs, which are usually rounded in exophytic species and elongated in endophytic species, are deposited in several ways. They may be dipped and washed into the surface of the water by the females in flight or deposited in long gelatinous strings or masses and attached to objects just under the surface of the water or on the undersides of chips or pieces of bark floating on the water or they may be inserted into logs or mud or in the tissues of living plants growing near or in the water. In the last case the females, sometimes accompanied by the males, may crawl down the stems under the water where they remain for a considerable length of time, apparently indifferent to their complete submergence and in no hurry to renew their supply of air. The females may also oviposit in such plants by merely extending the abdomen under the water. A single dragonfly female has been known to lay more than 800 eggs in a single mass. The nymphs or naiads can hardly be called beautiful and are not at all to be compared with the adults in vivacity. They are unattractive in form and movements, but their cryptic and often changing colors make them remarkably well adapted to the particular life they lead. They are to be found in fresh, or rarely brackish, water, living among the water plants, clinging to rocks or logs, or buried in the sand or mud at the bottoms of pools, lakes, and streams, and are occasionally seen in open water. All are highly predacious upon whatever forms of aquatic animal life can be overpowered, and they are equally given to cannibalism. Mayfly naiads and mosquito and gnat larvæ form a large part of their diet. After 10 to 15 instars, over a period of from 1 to 5 years the nymphs are fully grown. Crawling out of the water, they then attach themselves to some suitable object by means of their feet and emerge as adults through a slit in the dorsum of the head and thoracic region to take on a life of aerial predacity. Their prey is taken on the wing, caught and held in a sort of a trap formed by the forward position of the legs. Their food consists of a remarkably long and complete run of insects including many of the noxious gnats, midges, mosquitoes, and flies, and they thereby confer some benefit upon the human race in lessening the numbers of its tormentors and of disease-bearing insects. The winter is usually passed in the nymphal stage, but adults also hibernate or are active throughout most of the year in the warmer regions. On occasions dragonflies migrate in large numbers over long distances. The widely distributed north temperate species, *Libellula quadrimaculata* Linnæus, often appears in great numbers in parts of Europe while *Hemicordulia tau* Selys acts similarly in Australia. Although most species are diurnal and sun-loving, certain tropical species fly and feed at night.

External anatomy.—The adult has already been briefly characterized. The head is wide because of the large, laterally placed compound eyes which occupy most of the space and is pivoted on a very slender neck, giving it freedom of movement. Three ocelli occur on the dorsum just in front of the com-

pound eyes. The antennæ are very short, inconspicuous, and awl-shaped with from three to seven segments. The mouth parts are well developed for a predatory life. The mandibles are strong and sharply toothed, the maxillæ have unsegmented palpi and toothed and spined malæ, the submentum has a cleft ligula or median lobe and two-segmented labial palpi—the first segment in the form of a lateral lobe and the second as a movable hook. The palpiigers or

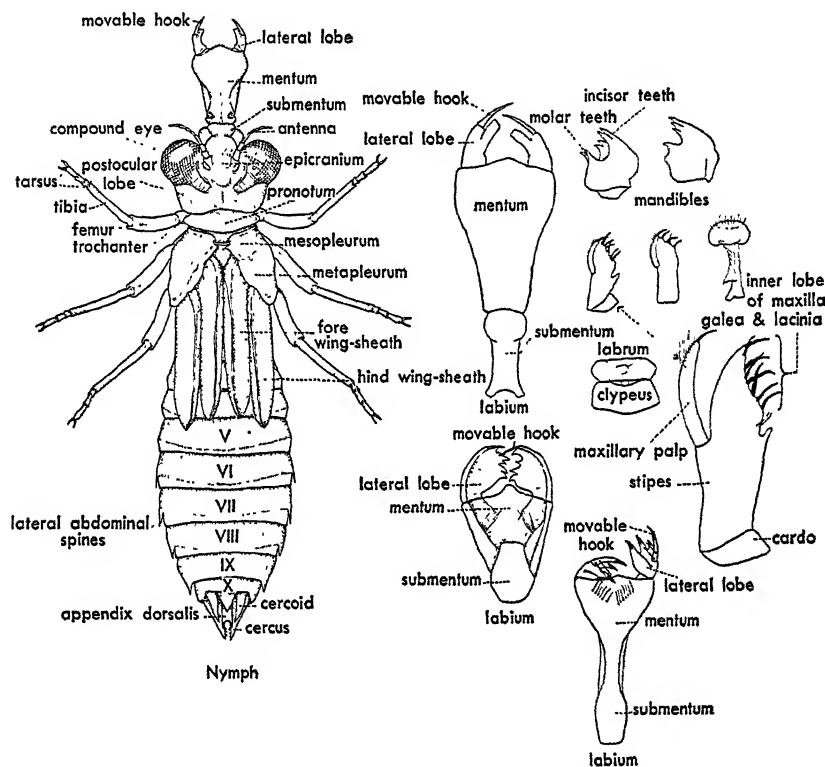


FIG. 81. The naiad of a dragonfly showing important characters and the mouth parts drawn separately.

side pieces are called squames or squamæ. The thorax is obliquely segmented so as to force the dorsal regions backwards and the ventral regions forwards, thus placing the legs near the head where they are especially useful as a basket for scooping up living prey captured on the wing. The legs are short and adapted only for perching. In some males the tibiæ are dilated. The three-segmented tarsi terminate in a pair of toothed claws between which there is a rudimentary empodium called the plantula. The wings are attached by means of a single axillary and are vibrated directly by the powerful thoracic muscles. The position of the wings in repose and some of the more important types of

venation are shown in the accompanying illustrations. Classification is based very largely upon venation, and a thorough knowledge can be acquired only by a careful study of the specimens and the work of competent odonatologists.

The greatly elongated abdomen is either cylindrical, somewhat flattened dorsally, or enlarged posteriorly. There are 10 well-defined segments and two rudimentary ones at the anal end. In the ANISOPTERA the males with angulate hind wings have small protuberances, auricles, on the second tergite, and in some species the third segment is constricted. The tergites extend downwards so as to conceal the spiracles and plural membranes and even to partially overlap the sternites. The cerci or superior appendages in both sexes are short and unsegmented. The supra-anal plate or inferior appendage is present in the males of ANISOPTERA and vestigial in males of ZYGOPTERA and in all females. Paraprocts are strongly chitinated in the males of ZYGOPTERA to form the inferior appendages. The females of all ZYGOPTERA and certain ANISOPTERA have a well-developed ovipositor while those in other members of the ANISOPTERA have the ovipositor aborted or vestigial. Although the male gonopore is situated on the ninth sternite, the penis with accessory armature is situated in a groove of the second sternite and arises from the penis vesicle on the anterior portion of the third sternite—a characteristic unknown in any other order of insects. In general the males may be distinguished by the copulatory groove on the second abdominal segment and by three or four caudal appendages and the females by the presence of only two caudal appendages. The males are also often more brightly colored. The two sexes are often seen pairing on the wing, either in tandem flight in which case the male holds the female damselfly by the prothorax or the female dragonfly by the back of the head by means of his caudal appendages, or in copulation in which case the female brings her abdomen forward to connect with the second sternite of the male. There are eight pairs of spiracles located on abdominal segments I to VIII and segment II of the thorax.

The nymphs are grotesque creatures that look like miniature prehistoric reptiles. They are robust or elongated with a rather thin, leather-like integument which may be rough and horny and are wholly aquatic, living on the bottoms in mud and sand or clinging to rocks, logs, and other places of lodgment. In coloration they are mostly somber or cryptic, and those species which inhabit the aquatic plants are often covered with algæ or overgrown with bryozoans. The first-born are peculiar in being still enclosed in a thin membranous shroud for a few seconds or minutes, during which brief period they are designated as pronymphs. After shedding this membrane they are in the second instar and begin their active life of preying upon all kinds of water animals that can be overpowered. The most remarkable thing about these insidious creatures is the unusually developed labium, which is long, jointed near the base, and extensile like a human arm. At the apex the two palps are provided with movable hooks and spines and act like a hand in grasping and holding living prey. The labium may be darted forwards with great speed and pre-

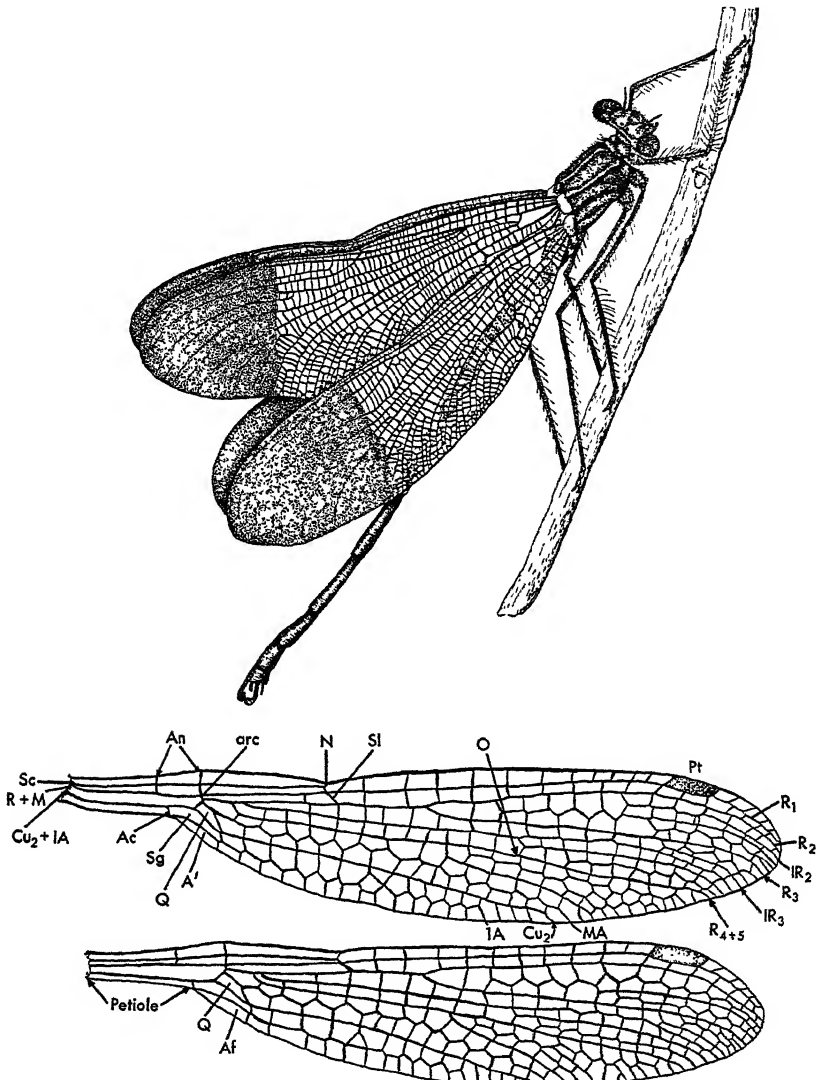


FIG. 82. Damselflies. The blackwing, *Agrion xquabile* (Say) and wings of *Lestes congener* Hagen. A', anal vein; Ac, anal crossing; Af, anal field; An, antenodal crossvein; arc, arcus; Cu, cubitus; M, media; MA, medio-anal link; N, nodus; O, oblique; Pt, pterostigma; Q, quadrangle; R, radius; Sc, subcosta; Sl, subnodus; Sg, subquadrangle. (Drawings by C.F. Harbison.)

cision. When not in use this organ is folded over the rest of the mouthparts like a mask.

The legs are quite long, and the articulation between the femur and the trochanter is sufficiently weak to constitute a breaking joint, which enables the insect to throw off the leg if entangled in debris or seized by a predator or cannibal. At the posterior end of the abdomen there are a pair of cerci and a dorsal median appendage which are rather short in the dragonflies but are modified to form the caudal gills of the damselflies. The cercoids, another pair of small horn-like structures above the cerci, appear in the fourth or fifth molt and give rise to the genitalia of the adults. The gills may be triangular, cylindrical, or flattened in cross section. The damselfly naiads also appear to obtain air from the rectal region and in some cases from spiracles. The naiads of some primitive members of the CALOPTERYGIDÆ have lateral, filamentous, abdominal gills on segments II to VII or II to VIII which are retained throughout life.

Internal anatomy. — The alimentary canal is a straight tube as long as the body and consists of a long narrow oesophagus, a somewhat enlarged crop, a rudimentary gizzard, a long mid-intestine lacking enteric cæca, a short hind intestine supporting from 50 to 70 Malpighian tubules and normally six rectal papillæ. There are two pairs of thoracic and eight pairs of abdominal spiracles. The large optical ganglia of the head are augmented by three thoracic and seven abdominal ganglia. The spermatozoa of the male form in sperm capsules in the sperm sac on the ninth segment and are transferred to the second segment prior to copulation.

In the naiads the gizzard is greatly developed and provided with internal grinding organs, the mid-intestine is shorter, and the Malpighian tubes are few at first but gradually increase in number until maturity is reached. There are eight abdominal ganglia and spiracles are present on the meso- and meta-thorax, of which only the spiracles on the mesothorax are functional when the naiad leaves the water. The metathoracic and abdominal spiracles are undeveloped. The dragonfly naiads breathe by means of gills located in a highly specialized branchial basket or barrel-like chamber in the rectum into which the water is drawn and expelled — the latter operation often with sufficient force to shoot the insect ahead in the water. The caudal gills of the damselflies have already been described.

Dragonflies and damselflies have a world-wide distribution, there being approximately 500 described genera and 4,500 species which are distributed as follows: Neotropical 1,200, Indo-Malaysian 1,000, Ethiopian 700, Australo-oceanian 400, Nearctic 650, and Palearctic 550. This distribution indicates very clearly that these insects are lovers of warm regions.

KEY TO SUBORDERS

1. Both pairs of wings similar in size, shape, and venation. (Damselflies.)

ZYGOPTERA p. 235

Wings dissimilar in shape and venation — the hind wings usually much wider at the bases. 2

2. Discoidal cell (Q) a simple quadrilateral, markedly different in fore and hind wings. (Diverse Damselflies.) **ANISOZYGOPTERA** p. 240
 Discoidal cell (Q) divided into a supra-triangle and a triangle. (Dragonflies.) **ANISOPTERA** p. 240

Suborder ZYGOPTERA Selys 1854

(Zy-gop'ter-a, from the Greek *ζυγόν*, yoke, + *πτερά*, wings.)

Damselflies.

These are the smaller and slenderer members of the order, slower and more erratic fliers which usually rest with the wings closed over the back. The females have well-developed ovipositors for inserting the eggs into the stems of water plants. The nymphs are also slender and possess three conspicuous caudal gills.

KEY TO SUPERFAMILIES

1. Wings usually with but two to four antenodal cross veins; arculus as near to the nodus as to the base of the wing; wings distinctly petiolate; mesopleura without oblique dividing suture (**CÆNAGRIONIDEA**) **CÆNAGRIOIDEA**
2. Wings with five or more antenodal cross veins; arculus equidistant or further from the nodus than from the base of the wing; wings less distinctly petiolate; mesopleura with a distinct oblique suture from the base of the fore wing to the middle coxa. (**AGRIONIDEA**) **AGRIOIDEA** p. 238

Superfamily CÆNAGRIOIDEA Tillyard 1926

KEY TO FAMILIES

1. Second branch of cubitus (Cu_2) strongly arched forwards at its base just beyond the apex of the discoidal cell (Q); discoidal cell very narrow and pointed apically; two or rarely three antenodal cross veins **SYNLESTIDÆ** p. 236
 Second branch of cubitus (Cu_2) straight or very slightly curved forwards at the base 2
2. Postnodal cross veins extend as straight lines across the subcosta from C to R_1 (Fig. 82) 3
 Postnodal cross veins do not all meet on the subcosta; discoidal cell open at base **HEMIPHLEBIDÆ** p. 236
3. Wings without supplementary sectors extending inwards from the distal portion of the posterior margin 4
 Wings with one or more supplementary sectors 5
4. Cu_2 long, extending beyond the middle of the wing; 1A present. (**CÆNAGRIONIDÆ**) **CÆNAGRIDÆ** p. 236
 Cu_2 short, reaching the margin of the wing before the middle; 1A absent **PROTONEURIDÆ**

5. Veins 1RS and R_{4+5} arising nearer to the nodus than to the arculus; apical angle of the discoidal cell obtuse, rarely somewhat acute . . . 6
 Veins 1RS and R_{4+5} arising near the base of the wing and closer to the arculus than to the nodus; discoidal cell with distal angle very acute
 LESTIDÆ p. 237
6. Nodus at or between basal third or fourth of wing margin; pterostigma normal in shape MEGAPODAGRIDÆ p. 237
 Nodus at or between basal sixth and seventh of the wing margin; pterostigma absent, indistinct, or irregular in shape PSEUDOSTIGMATIDÆ

Family SYNLESTIDÆ Tillyard 1926 (Syn-les'ti-dæ, from the Greek prefix σύν, with or together, combined with LESTIDÆ from ληστής, a robber, a rover). A small family of primitive damselflies represented by the genera *Synlestes* Selys and *Chorismagrion* Morton (Australasia), *Megalestes* Selys (Indian), *Chlorolestes* Selys (Ethiopian), and *Perilestes* (Neotropical).

Family HEMIPHLEBIIDÆ Tillyard 1926 (Hemi'phle-bi'i-dæ, from the Greek ἡμι, half, + φλέω, φλεβός, vein).

The only known species is the tiny Australian *Hemiphlebia mirabilis* Selys, a metallic-green damselfly only 10–12 mm. long which, according to Tillyard (1926), is probably the most archaic odonate still in existence.

Family CENAGRIDÆ Tillyard 1926 (CENAGRIONIDÆ Karsch 1894) (Co-en'ag-ri'i-dæ, from the Greek κοινός, common, usual, + ἄγριος, wild, savage).

This is the dominant family of damselflies of very general and wide distribution throughout the world. The important genera are: *Cenagrion* Kirby, *Ischnura* Charpentier, and *Enallagma* Charp. (all cosmopolitan), *Argia* Rambur (American), *Nehalennia* Selys (Holarctic and Neotropical), *Platycnemis* Charp. (Palearctic), and *Chlorocnemis* Selys (Ethiopian). The smallest known members of the order are to be found in the Australian genera *Agriocnemis* Selys and *Austrocnemis* Tillyard which have a wing expanse of only 18 mm. or 0.7 in. The smoky-winged argia, *Argia fumipennis* Burmeister, the type species of this large and complex genus and common throughout the southeastern part of the United States, brown and black with uniform smoky-brown wings, is 33 mm. long and has an expanse of 41 mm. *A. moesta* (Hagen), a dark-brown, tawny, and black species with yellow abdominal spots and rings, is one of the largest North American species, measuring 43–45 mm. in length and with a wing expanse of 50–56 mm. It occurs in the southwestern United States and in Mexico. The bluets or members of the genus *Enallagma* are a large North American group of 38 species which are well distributed throughout the country. The adults fly close to the surface of the water and rest on vegetation around the margins of streams, lakes, and pools, and some species inhabit brackish water and desert alkali pools. The forktails of the genus *Ischnura*, although cosmopolitan in distribution, are represented by only 15 species in North America. The adults often occur in great numbers, and the females may have

a blue or green and black color phase or else a yellow or orange and black phase. *I. denticollis* Burmeister, a black, green, and blue damselfly only 28 mm. long, is the smallest species in the western part of the United States and in Mexico. *I. prognatha* Hagen, of the yellow and black phase, is the largest and finest member of the genus in this country. It is 36–38 mm. long and occurs in the southern states. *I. verticollis* Say, 20–30 mm. long, is the commonest species east of the Rocky Mountains.

Family LESTIDÆ Jacobson and Bianchi 1905 (Les'ti-dæ, from the Greek ληστής, a rover, a robber).

The members of this family are large damselflies of cosmopolitan distribution. They are for the most part arrayed in combinations of bronze, blue,

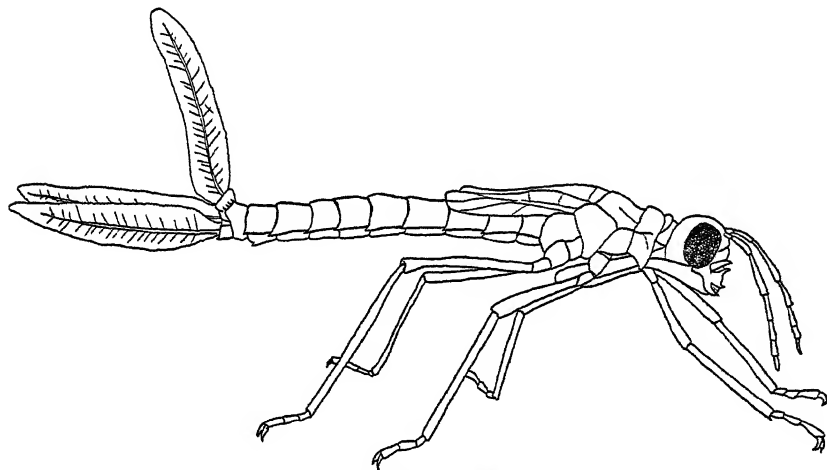


FIG. 83. Naiad of the damselfly, *Lestes stultus* Hagen. (Drawing by C. F. Harbison.)

green, and yellow hues. The wings are usually held upwards and backwards in repose, excepting in the Australasian species, where they are entirely closed. The nymphs have long, narrow, spatulate gills and a very slender mentum of the labium. They inhabit thickly vegetated marshlands. The important genera are *Lestes* Leach (cosmopolitan), *Sympycna* Charp. (Palearctic), *Archilestes* Selys (American), and *Austrolestes* Tillyard (Australian). The largest North American species, *Lestes vigilax* Hagen, a metallic green, bronze, and yellow species, attains a length of 53 mm. and a somewhat greater wing expanse.

Family MEGAPODAGRINIDÆ Tillyard 1926 (Meg'a-pod'ag-ri'i-dæ, from the Greek μέγας, great, + πούς, ποδός, foot, + ἄγριος, wild, in a wild state).

The important genera are *Megapodagrion* Selys (Neotropical), *Argiolestes* Selys and *Lestoidea* Tillyard (Australian), *Podolestes* Selys and *Podopteryx* Selys (Austro-Malaysian). The nymphs are robust, have leaf-like caudal gills,

and inhabit rocky streams. The adults of *Argiolestes*, the dominant genus in Australia, and of *Podopteryx* rest with their wings outspread as do dragonflies. Species of *Podopteryx* may have a wing spread of 4 in.

Superfamily AGRIOIDEA¹ Tillyard 1926

KEY TO FAMILIES

1. Wings indistinctly petiolate at base, without a distinct angle on hind margin at junction of petiole and the rest of the wing; antenodal cross veins numerous between the costa, subcosta, and radius 2
Wings distinctly petiolate at base, with a distinct angle on the hind margin at the junction of the petiole and the rest of the wing; antenodal cross veins few or absent between the costa, subcosta, and radius **AMPHIPTERYGIDÆ**
2. Sectors of arculus arising near or below the middle of arculus; discoidal cell with opposite sides equal 3
Sectors of the arculus arising at upper distal corner of arculus, really from the radius; discoidal cell with the basal side longest **POLYTHORIDÆ**
3. Sectors of the arculus arising near middle of arculus; pterostigma distinct, long 4
Sectors of the arculus arising from lower part of arculus; pterostigma often indistinct or obsolete in male; entire wing densely reticulate
AGRIIDÆ
4. Antenodal cross veins between the costa and radius mostly continuous; arculus much closer to the wing base than to the nodus **EPALLAGIDÆ**
Antenodal cross veins between the costa and the radius not continuous beyond the arculus; arculus often about midway between wing base and nodus **LIBELLAGINIDÆ**

Family AGRIIDÆ Tillyard 1926 (CALOPTERYGIDÆ) (Ag-ri'i-dæ, from the Greek ἄγριος, wild, fierce).

A large family of dominant and highly specialized damselflies, widely distributed and especially well represented in the tropics. The most important genera are the following: *Agrion* Fab. (*Calopteryx*) (Holarctic), *Heterina* Hagen (American), *Pentaplebia* Förster and *Sapho* Selys (Ethiopian), *Vestalis* Selys (Indo-Malaysian), and *Neurobasis* Selys (Indo-Australasian).

The common ruby spot, *Heterina americana* Fabricius, copper-bronze and metallic green with ruby-red spots covering the bases of both pairs of wings of the males which are amber yellow in the females, 44 mm. in length and having an expanse of 58 mm., is a widely distributed North American species, abundant along rivers and creeks where the long-legged nymphs live in the riffles.

¹ Also known as AGRIONOIDEA.

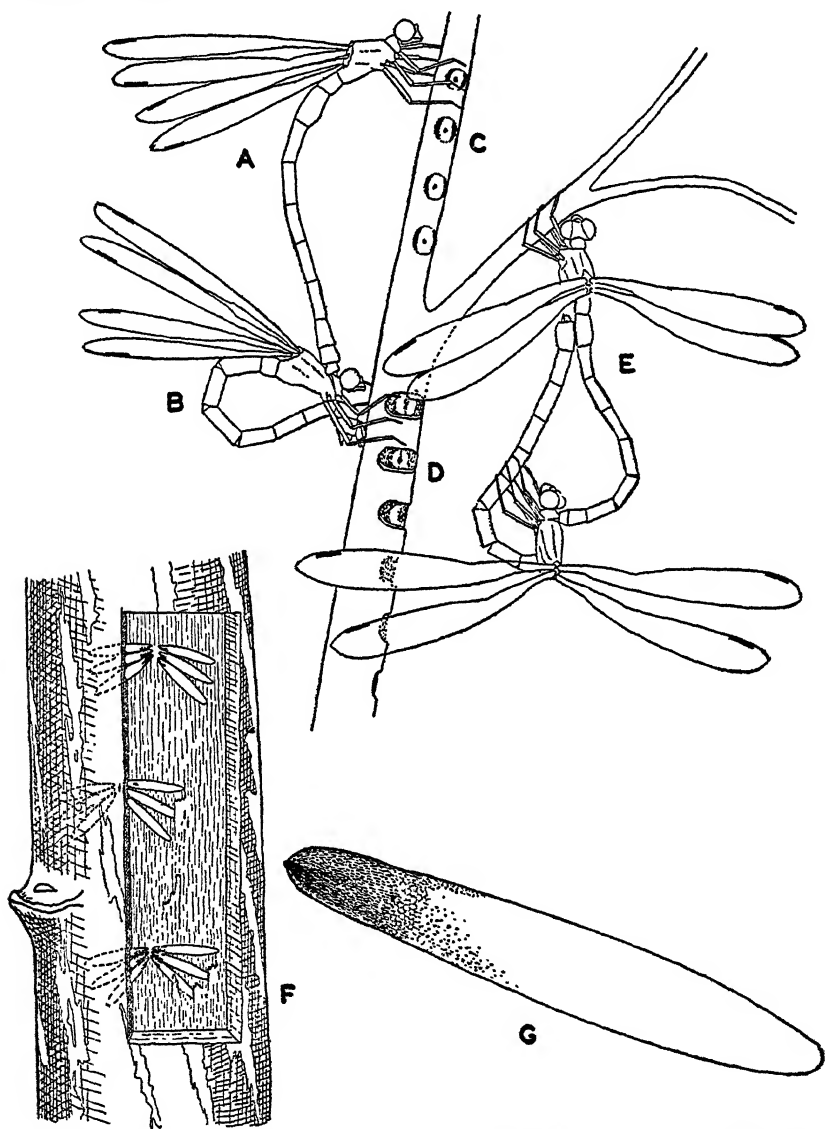


FIG. 84. Drawing of the damselfly, *Archilestes californica* McLachlan. A, male holding female; B, female ovipositing in the stem of a water plant; C, one-year-old egg scars; D, two-year-old egg scars; E, male and female copulating; F, section of plant cut away to show eggs; G, egg greatly enlarged. (After Kennedy, 1916.)

Suborder ANISOZYOPTERA Handlirsch 1906

(An-i'so-zy-gop'ter-a, from the Greek combining form *ἄνισος*, unequal or dissimilar, + ZYOPTERA).

Diverse Damselflies.

A small suborder with characters simulating both the damselflies and the dragonflies. It contains but a single living family and two living representatives.

Family EPIOPHLEBIIDÆ Muttkowski 1910 (Ep'i-o-phle-bi'i-dæ, from the Greek *ἐπί*, upon, after, + *φλέω*, *φλεβός*, vein).

The species *Epiophlebia superstes* Selys occurs in Japan and a nymph has been taken in the Himalayas. Only the larva of *E. laidlawi* Tillyard of India is known.

Suborder ANISOPTERA Selys 1834

(An'i-sop'ter-a, from the Greek *ἄνισος*, unequal, + *πτερά*, wings.)

Dragonflies.

Large, strong-flying, hawking insects which are among the most versatile of all aerial animals. They usually perch with the somewhat unequal wings held at right angles to the body in a horizontal plane. The nymphs are robust and often very large. The gills are concealed within the rectal cavity.

KEY TO SUPERFAMILIES

1. Antenodal cross veins between the costa and radius not continuous, except the heavy A_{x1} and A_{x2} ; triangles (t) in both pairs of wings homologous; labial palpi two-segmented ÆSCHNOIDEA
- Antenodal cross veins between the costa and radius continuous, except the last one or two; triangles of both pairs of wings noticeably different in form and position, being much nearer the arculus in the hind wings LIBELLULOIDEA p. 243

Superfamily ÆSCHNOIDEA Selys 1840

A large group of swift-flying hawking dragonflies.

KEY TO FAMILIES

1. Hind wings without a definitely restricted anal loop; eyes separated above by a wide space 2
- Hind wings with a clearly marked anal loop; eyes either meeting above or separated by a narrow space 3
2. Ovipositor well developed; with two oblique cross veins between the

third and fourth branches of the radius (R_3 and $1R_3$); anal angle of the hind wing of the male angularly produced; inferior appendage of the male not bifid; very large dragonflies

PETALURIDÆ

Ovipositor reduced to a pair of valves attached to the eighth segment; with one oblique cross vein between R_3 and $1R_3$; inferior appendage of the male bifid

GOMPHIDÆ

3. Third branch of the radius (nodal sector or R_3) strongly arched just below the pterostigma; a heavy cross brace vein just below base of the pterostigma; eyes generally conjoined for a considerable distance above

ÆSCHNIDÆ p. 242

Third branch of the radius (R_3) gently curved; brace vein absent; eyes just touching or slightly separated above; ovipositor long

CORDULEGASTERIDÆ p. 242

Family PETALURIDÆ Tillyard 1926 (Pet'-al-ur'i-dæ, from the Greek πέταλος, outspread, broad, flat, + οὐρά, tail).

A small family containing about a dozen species of which the important genera are: *Petalura* Leach (Australia), *Uropetala* Selys (New Zealand), *Tachopteryx* Selys (Holarctic), *Phenes* Rambur (Neotropical), and *Tanypteryx* Kennedy (Nearctic). The eastern grayback, *Tachopteryx thoreyi* Hagen, a giant species 78 mm. long, wing expanse of 106 mm., and grayish in color, is the only representative of the family in the eastern United States. The western grayback, *Tanypteryx hageni* Selys, a smaller species 55 mm. long and with a wing expanse of 74 mm., occurs in the western states and is grayish, spotted with black.

Family GOMPHIDÆ Banks 1892 (Gom'phi-dæ, from the Greek γόμφιος, a grinder tooth). Clubtails.

An important family of some 350 species occurring throughout the world. The adults are large dark dragonflies with greenish or yellowish stripes. They are stream loving and often rest on the ground or on rocks exposed above water. Because of their posteriorly enlarged abdomens they are called clubtails. The nymphs hide in debris or burrow in the sand and mud at the bottom, and some species have the posterior abdominal segment greatly extended so as to secure a supply of water when deeply buried. They have four-segmented antennæ and two-segmented fore tarsi. The genera are *Gomphus* Leach and *Ophiogomphus* Selys (Holarctic), *Erpetogomphus* Selys (American), *Lindenia* Haan (Palæarctic), *Ictinus* Rambur (Indo-Australasian), and *Austrogomphus* Selys (Australian). *Gomphus*, the largest genus in North America, is represented by about 47 species. Its species are clear-winged dragonflies with greenish or yellowish bodies, striped brown or black. *G. dilatatus* Rambur, with a length of 70 mm. and an expanse of 92 mm., is the largest North American species, reported only from Georgia and Florida; *G. abbreviatus* Hagen, 34 mm. long and with an expanse of 52 mm., appears to be the smallest. It ranges from Pennsylvania to Maine.

Family ÆSCHNIDÆ Burmeister 1839 (Æsch'ni-dæ, probably from the Greek αἰσχος, ugly, ill-favored). Large Dragonflies, Darners.

This family contains some of the largest, swiftest, and most voracious dragonflies, often called darners. They are often brilliantly colored and marked with blue and green and may be seen hawking until twilight. The nymphs live in vegetation in still and slowly moving waters. There are about 250 described species occurring throughout the world but most abundantly in the tropics. Among the important genera are: *Anax* Leach and *Æschna* Illiger (cosmopolitan), *Gynacantha* Rambur (Southern Hemisphere), *Basiaeschna* Selys (Nearctic), and *Austrophlebia* Tillyard (Australian). Of the North American species the big green darter, *Anax junius* Drury,¹ is perhaps the commonest and best known member of the family. It has a green thorax and bluish abdomen, is 76 mm. long, and has an expanse of 104 mm. The adults have been observed in large migrating swarms. The nymph, though nearly always found in fresh water, may also be found in brackish waters. *A. walsinghami* McLachlan, a California species, is the largest North American dragonfly, having a length of 105 mm. and an expanse of 122 mm. The thorax is green and the abdomen blue except for the basal segment which is red.

The genus *Æschna* is composed of large cosmopolitan species called the blue darners although the colors may be various shades of blue, green, and yellow. The thorax has a pair of stripes on each side which are an important diagnostic character. They are large, strong fliers, and often seen miles from their breeding places. Some species rest in the shade during the heat of the day. There are 18 species in North America. *Æschna cærulea* Burmeister, a common European species, also occurs in the northeastern parts of North America, chiefly in Canada. *A. constricta* Say is a large blue or brownish species devoid of yellow markings. The large nymphs, prior to emergence, have been taken in great numbers on the undersides of pieces of pine bark floating in the lakes of the Sierras and are used to good advantage in trout fishing (Essig, 1926).

Family CORDULEGASTERIDÆ Banks 1892 (Cor'du-le-gas-ter'i-dæ, from the Greek κορδύλη, club, + γαστήρ, belly; referring to the club-shaped abdomen).

A small family of large yellow and black dragonflies distributed throughout much of the world. It is represented by some 25 species in three well-known genera, *Cordulegaster* Leach (Holarctic), *Anotogaster* Selys (Palæarctic and Indo-Malaysian), and *Allogaster* Selys (Indo-Malaysian). Members of the genus *Cordulegaster* are called biddies by Needham and Heywood (1929). *C. dorsalis* Hagen, 76 mm. long and with an expanse of 94 mm., ranges along the Pacific coast from southern California into Alaska. It breeds in the coastal and mountain streams and lakes.

¹ A splendid account and life history of this fine species is given by Needham and Heywood (1929). A good colored plate is presented by Pickwell, Duncan, et al. (1933).

Superfamily LIBELLULOIDEA Selys 1840

A large group of well-known species commonly called skimmers because of their sustained and continual flight over water. There are two families.

KEY TO FAMILIES

1. Triangle in fore wing with its upper side more than half the length of the basal side; anal angle of the male wing usually angulate; posterior margin of the eyes with slight projection; fore tibia of male with a keel **CORDULIDÆ**
- Triangle in fore wing greatly widened so that the upper side is usually less than half the length of the basal side; anal angle of the wing of both sexes rounded; posterior margin of the eyes evenly rounded; fore tibia of male without keel **LIBELLULIDÆ**

Family CORDULIDÆ Banks 1892 (Cor'du-li'i-dæ, from the Greek κορδύλη, club; from the posterior enlargement of the abdomen).

A large family of strong-flying, often brightly colored, dragonflies comprising about 200 species, especially well represented in North America and Australia but also widespread as indicated by the distribution of the following important genera: *Cordulia* Leach (Holarctic), *Somatochlora* Selys (Holarctic and Australian), *Macromia* Rambur (almost cosmopolitan), *Tetragoneuria* Hagen (Nearctic). In the largest genus, *Somatochlora*, North America is represented by 21 of the 36 known species. They are mostly metallic blue and green species with yellow stripes, spots, and bands and black legs.

Family LIBELLULIDÆ Stephens 1836 (Li'bel-lu'li-dæ, perhaps from the Latin *libella*, a level; in reference to the horizontal position of the wings). Skimmers, Topers.

A large family of common, nonmetallic though brightly colored dragonflies, whose abdomens are usually triangular in cross section and whose wings are frequently partly clouded. The females are without a well-developed ovipositor. There are approximately 570 species, widely distributed but more abundant in the tropics than elsewhere. The important genera are: *Libellula* Linn., *Leucorrhinia* Brittinger, and *Sympetrum* Newman (Holarctic), *Pantala* Hagen (cosmopolitan), *Tramea* Hagen (eastern United States), *Celithemis* Hagen (Nearctic), and *Crocothemis* Brauer (Ethiopian and Indo-Australian).

In *Celithemis* the wings are usually tinted brown or gold and rarely veined red. The nymphs live in aquatic vegetation. Adults of the genus *Libellula* are called skimmers and are probably the best known of the dragonflies. The wings are usually clouded in small or large areas. The nymphs are hairy and live in the debris on the bottoms. The widow, *L. luctuosa* Burmeister, a blackish species 47 mm. long with broad dark basal wing bands, ranges over much of the country east of the Rocky Mountains. The big red skimmer, *L. saturata* Uhler,

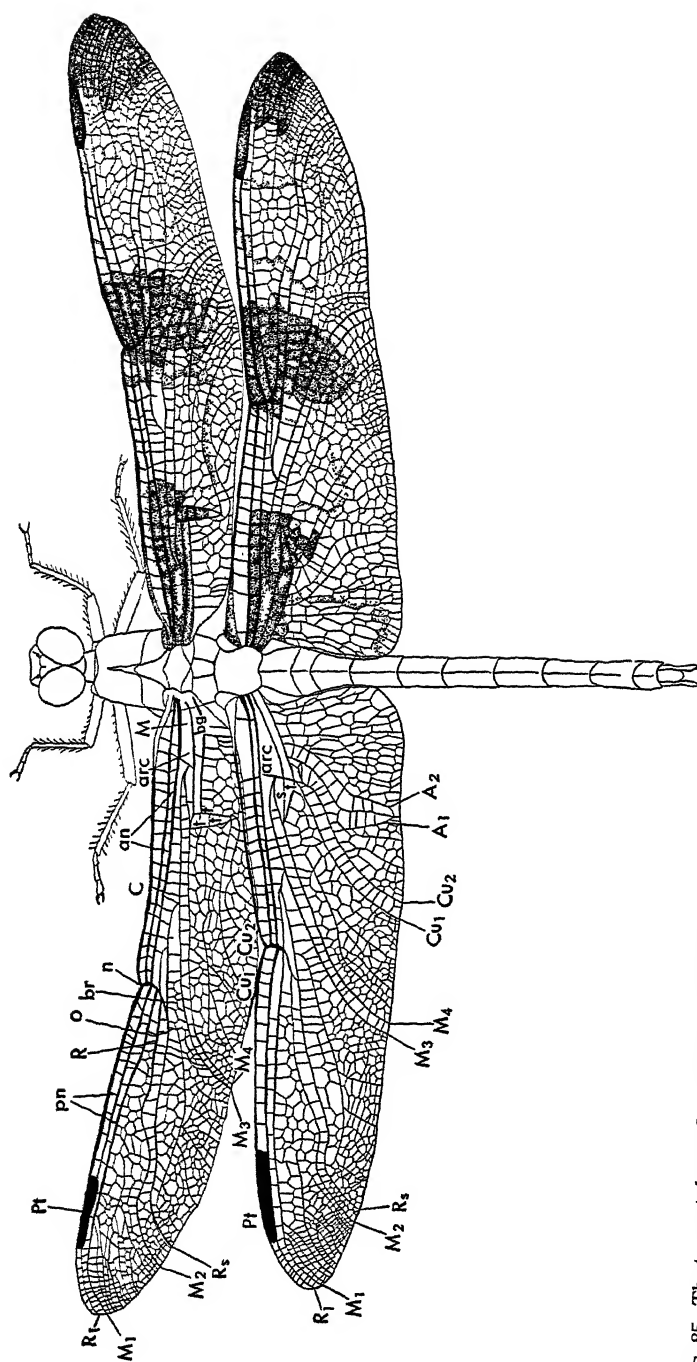


FIG. 85. The tenspot dragonfly, *Libellula pulchella* Drury. A, anal vein; an, antennodal crossvein; arc, arcus; bg, base of anal vein; br, bridge; C, costa; Cu, cubitus; M, media; n, nodus; o, oblique; pn, postnodal crossvein; Pt, pterostigma; R, radius; R₁, radial sector; s, subtriangle; t, triangle.

a fine large reddish dragonfly 55 mm. long, occurs generally west of the Rocky Mountains. The ten spot, *L. pulchella* Drury, a superb species with three large brown spots on each wing and 52 mm. long, and the four spot, *L. quadrimaculata* Linnæus, a smaller species 45 mm. long, with a conspicuous brown basal and a very small nodal spot on each wing, are both widely distributed throughout much of the whole country. The toppers of the genus *Sympetrum* are for the most part rather small, attractive, red species common throughout the country about ponds. They are abundant late in the season and, because they are rather slow fliers, are an easy prey for amateur entomologists. The nymphs inhabit algæ and other dense aquatic vegetation.

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CHAPTER XXIV

21. Order THYSANOPTERA¹ Haliday 1836

(Thy'sa-nop'ter-a, from the Greek *θύσανος*, a fringe, a tassel, + *πτερά*, wings; referring to the marginal fringe of hairs on the wings.) German, Blasenfüsse. French, Thrips.

Thrips.

Minute to small, slender, terrestrial insects; somewhat compressed dorsally or almost cylindrical, with simple metamorphosis; mouth parts modified for piercing, chafing, and sucking; antennæ short, six- to nine-segmented; compound eyes conspicuous; three ocelli present in winged forms; wings absent, vestigial, or well developed, two pairs, long and narrow, with few or no veins, fringed with short and long hairs or bristles; legs short; tarsi one- or two-segmented or heteromorous, with one or two claws and a bladder or hoof-like apex; abdomen 10- to 11-segmented with an ovipositor or terminating in a tubular prolongation.

The members of this order form a homogenous group readily distinguished from other insects by their characteristic small size, shape, and structures, including especially the peculiar fringed wings which appear only in certain other very small insects.² When at rest the wings are folded flat over the dorsum with the bristles lying against the wing margins.

The adult thrips vary in size from the small *Thrips minutissima* Linn., 0.6–0.9 mm. long, and the grape thrips, *Drepanothrips reuteri* Uzel, of Europe and North America, 0.7–0.8 mm. in length, to the giant thrips, *Acanthinothrips spectrum* (Haliday), of Australia, which attains a length of 14 mm. or slightly

¹ The early entomologists grouped the thrips with certain other insects without understanding their true relationships. Some of the more specific designations have been: genus *Physapus* DeGeer 1744; genus *Thrips* Linnaeus 1758 (order HEMIPTERA); family VERSITARES or PHYSAPODES Duméril 1806 (order HEMIPTERA); THRIPSITES Fallén 1814 (order HEMIPTERA); family THRIPSIDA Leach 1815 (order OMOPTERA, tribe APHIDES); PHYSAPIDA Leach 1817; PHYSAPI Latreille 1825 (family HYMENELYTRA, tribe THRIPSIDES); family THRIPIDÆ Stephens 1829 (order HOMOPTERA); THRIPOIDES Burmeister 1829; THRIPSITES Newman 1835; THYSANOPTERA Haliday 1836 (first order name); PHYSOPODA Burmeister 1838 (suborder of the order GYMNOGNATHA, lists THRIPSITES Newman and THYSANOPTERA Haliday as synonyms); PHYSAPODA Walker 1852; THRIPSINA Newman 1855; order THYSANOPTERA, family THRIPIDIDÆ, Fitch 1855; THRIPIDÆ, Packard 1869 (a family of the order HEMIPTERA); PHYSAPODES Scudder 1886; PHYSOPODA Comstock 1888; THYSANOPTERA Hinds 1902. Modern systematists generally agree on the name THYSANOPTERA as the proper order designation.

The author is indebted to S. F. Bailey for assistance in the preparation of this chapter.

² Other insects with fringed wings are members of several families of minute parasitic HYMENOPTERA, certain small moths of the order LEPIDOPTERA, and members of the coleopterous families TRICHOPTERYGIDÆ, SPHERIIDÆ, and PTILIIDÆ.

more than $\frac{1}{2}$ in.¹ The form is always elongate, but some species are notably short, wide, and flat. Members of the genus *Ædaleothrips* are ant-like in form. The color range is restricted to various shades of yellow, tan, orange, reddish, brown, or wholly black, or combinations of these hues. The wings may be the

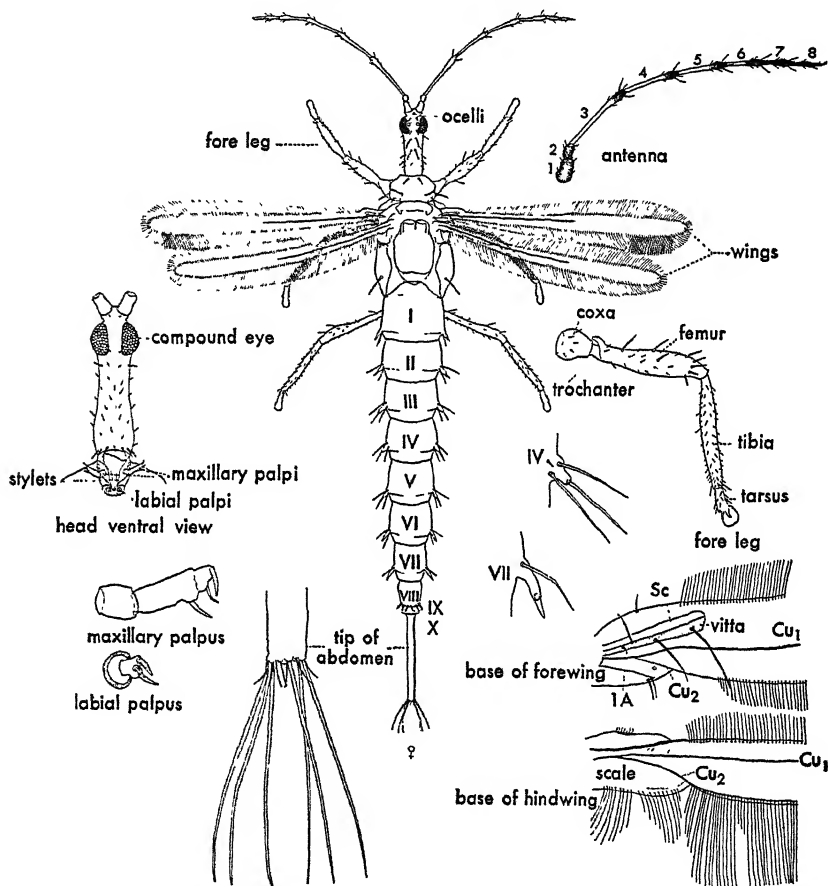


FIG. 86. *Acanthinothrips spectrum* (Haliday), indigenous to Australia and one of the largest species of thrips.

color of the body or paler and streaked or mottled with other darker shades. The adults crawl or run with a slow, even gait or run very rapidly and leap and fly away with great agility. The condition of the feet is also peculiar in that in many species the tarsus is terminated with a retractile bladder-like organ which, when expanded, is thought to aid the insect in adhering to smooth surfaces.

¹ According to Bailey, the largest New World species is *Dasythrips regalis* Hood, 10–12 mm. long and with a greater wing expanse. It occurs in the jungles of Peru.

Some species in crawling also curve the abdomen up over the back — a pose assumed by the young as well as by the adults.

Thrips are to be found generally upon all types of vegetation and are perhaps most abundant in flowers and on the leaves of the host plants, but they may also occur on the fruits and twigs. Some species appear to be scavengers upon dead vegetable matter, sap, and fungi while a considerable number are predacious upon mites, aphids, other thrips, and various minute forms of animal life and the eggs and young of larger insects. Certain Australian species belonging to the genera *Kladothrips*, *Choleothrips*, *Haplothrips*, and *Eothrips* produce true galls or pseudogalls on the leaves of trees in which the young are reared (Moulton, 1927). Thrips injure plants by destroying the cells of the living leaf and fruit tissues, by causing sterility, and also by disseminating bacterial viruses and fungus diseases. Bailey (1935) has listed four species of *Thrips* and three species of *Frankliniella* as carriers of plant diseases. Many other genera are also suspected of being vectors of such diseases. Thrips are thought to be beneficial by pollinating flowers. They often appear in great swarms and not only destroy growing crops but cause considerable annoyance to human beings by getting into the eyes, ears, nose, mouth, clothing, and even by biting to some extent. Farm laborers are often quite severely bitten during hot dry weather, apparently in an attempt on the part of the insects to secure moisture rather than to suck blood (Bailey, 1936). Migrations of adults of several species have been observed, and I have seen the tobacco or onion thrips, *Thrips tabaci* Lind., fairly fill the air over a bean field in California on a warm late summer afternoon just before sunset.

Thrips are normally bisexual, the sexes being quite similar except that the males are somewhat smaller and the females, in the TEREBRANTIA, have an ovipositor. Both sexes or either may be wingless, brachypterous, or winged, and in a few species all of these conditions occur.

Parthenogenesis is not uncommon, and in a number of species, notably the greenhouse thrips, *Heliothrips hæmorrhoidalis* Bouché, and the pear thrips, *Tæniothrips inconsequens* (Uzel), males are exceedingly rare or unknown. Members of the genera *Actinothrips*, *Diceratothrips*, *Elaphrothrips*, and *Zeuglothrips* give birth to living young.

Reproduction by oviparity and ovoviviparity. The eggs vary in shape from elongate-oval to reniform. They are laid at random or in groups on the exterior or in cracks, crevices, galls, and under bark or debris by the TUBULIFERA or they may be inserted within the tissues of the plants by means of the sharp sickle-like ovipositor of the female by the TEREBRANTIA. The eggs are small, some scarcely visible to the unaided eye and may be deposited in great numbers. Those inserted in plant tissues may be exposed to view with the aid of fine instruments and a good hand lens or a microscope. Their location is evidenced by the puncture and swelling of the surrounding tissues.

The eggs are laid in the early spring and throughout the summer and hatch in a few days or a week or more. The young literally push out through the punctures made by the female in deposition or they escape freely from those

eggs laid exteriorly on the host. The young are pale whitish, yellowish, or transparent in color or they may be of the same general color as the adult, or in some instances brilliant yellow, orange, or red. Some, like the bean thrips, *Hercothrips fasciatus* (Pergande), are whitish with numerous small red spots and blotches over the surface. They are rather slow and inactive as compared with the adults and move about very little, being more occupied with feeding than roving. Their excrement is deposited as small dark drops which may almost completely cover the surfaces of the parts infested and is characteristic of these insects, but the injury they cause may be confused with that of mites and certain homopterous insects. They pass through from two to four instars. Wing pads may appear in the prepupal stage after the second ecdysis, followed by a single prepupal stage of a short or long duration, there being one in the TERREBRANTIA and two in the TUBULIFERA.

Certain members of the family ÆOLOTHRIPIDÆ, including *Æolothrips fasciatus* (Haliday), *Franklinothrips tenuicornis* Hood, *Ankothrips yuccæ* Moulton, and *A. gracilis* Moulton spin cocoons above or below ground in which to pupate.

Normally there are five to seven generations a year, but in the case of the pear thrips there is but a single generation, and the period from the middle of May or early June to the early part of November is passed in the prepupal and pupal stages in the soil from 4 to 10 in. under the surface. The adults emerge in February, feed on the buds and blossoms, oviposit in the blossom petioles, and die, and disappear in March and April.

IMPORTANT ANATOMICAL CHARACTERS

External	Internal
<p>Size — 0.5–14.0 mm. in length.</p> <p>Shape — slender, dorsally depressed, or cylindrical.</p> <p>Color — various shades of yellow and brown; also whitish or black; some young red.</p> <p>Integument — tough and often well sclerotized for such small insects.</p> <p>Head — hypognathous, free, without neck.</p> <p>Compound eyes — large, conspicuous, rounded; sometimes with few facets.</p> <p>Ocelli — two or three in winged forms, absent in apterous forms.</p> <p>Antennæ — six- to nine-segmented; bristly; sometimes appear 10-segmented; with circular and horn-like sensoria.</p> <p>Mouth parts — arise from base of head and extend in a cone beneath the prosternum; asymmetrical; piercing and sucking. Clypeus — triangular, asymmetrical; labrum — symmetrical; man-</p>	<p>Digestive System.</p> <p>Alimentary canal — chitinized pharynx or sucking pump similar to HEMIPTERA in head; mid-intestine — large, composed of three parts, anterior portion large, posterior part coiled and tubular; hind intestine — short and straight. Malpighian tubes — four.</p> <p>Salivary glands — normally two pairs in the abdomen and thorax (three pairs in thorax of <i>Trichothrips</i>).</p> <p>Respiratory System.</p> <p>Well-developed tracheal system, with nine or ten pairs of spiracles; one or two pairs on thorax (one or both on the mesothorax or frequently one on the metathorax) and eight pairs on the abdomen (one on each segment I to VIII inclusive).</p> <p>Circulatory System.</p> <p>Short heart in abdominal segment VIII extends forwards as the aorta.</p>

IMPORTANT ANATOMICAL CHARACTERS—*Continued*

External	Internal
<p><i>dibles</i> — stylet-like, only the left one developed; <i>maxillæ</i> — side plates with one or two stylets and two- to eight-segmented palpi; <i>labium</i> — broad and short; <i>ligula</i> — very small with two minute paraglossæ; <i>palpi</i> — one- to four-segmented. The arrangement of the mouth cone is: <i>Exterior</i>: labrum in front; maxillæ on sides; labium behind. <i>Interior</i>: left mandible elongated, piercing; right mandible rudimentary; three stylets associated with bases of maxillæ and hypopharynx. <i>Sucking pump</i> in head chamber.</p>	<p>Nervous System. The brain, subœsophageal ganglion and prothoracic ganglion fused to form the anterior nerve center; the meso- and methathoracic ganglia are separate; abdominal ganglion in segment I only; median abdominal nerve cord.</p>
<p>Thorax — Prothorax — usually free, longer than either the meso- or the metathorax.</p>	<p>Reproductive System.</p>
<p>Meso- and metathorax — fused.</p>	<p><i>Male</i> —</p>
<p><i>Legs</i> — small, similar, or fore pair enlarged. <i>Tarsi</i> — one- or two-segmented; aborted; often with protrusible vesicle or hoof-like enlargement at apex and with single or paired claws; spurs absent or present on the femora and tibiæ, and tarsi.</p>	<p><i>Testes</i> — fusiform, one pair.</p>
<p><i>Wings</i> — absent, greatly reduced or two pairs present; long and narrow; similar; small anal area usually present; few or no veins; veins often spined; long hairs or spines closely set around margins; folded flat over abdomen, fringe folds closely along the wings so that the insects may appear wingless.</p>	<p><i>Vasa deferentia</i> — short.</p>
<p><i>Spiracles</i> — usually two pairs — one pair each on the mesothorax and metathorax (pair on the latter may be absent in some forms).</p>	<p><i>Ejaculatory duct</i> — swollen anteriorly where it receives ducts of one or two pairs of large accessory glands.</p>
<p>Abdomen — normally 10-segmented, some with a very small 11th segment; basal segment closely attached to thorax; posterior segment tubular in TUBULIFERA.</p>	<p><i>Female</i> —</p>
<p><i>Spiracles</i> — one pair each on abdominal segments I to VIII inclusive.</p>	<p><i>Ovaries</i> — short panoistic ovarioles.</p>
<p><i>Cerci</i> — absent.</p>	<p><i>Receptaculum seminis</i> — present.</p>
<p><i>Genitalia</i> — in the male, complicated.</p>	<p><i>Accessory glands</i> — present.</p>
<p><i>Ovipositor</i> — sickle-shaped, serrate, exerted between sternites VIII and IX in TEREBRANTIA, absent in TUBULIFERA.</p>	

Fossils of thrips have been taken in shales, amber, and copal. The family THIRIPIDÆ is mostly represented in the Tertiary formations. Specimens have been collected as follows: two species in the Oligocene of the White River, Colo.; three species in the Lower Oligocene of Aix, France; and 11 species in the Upper

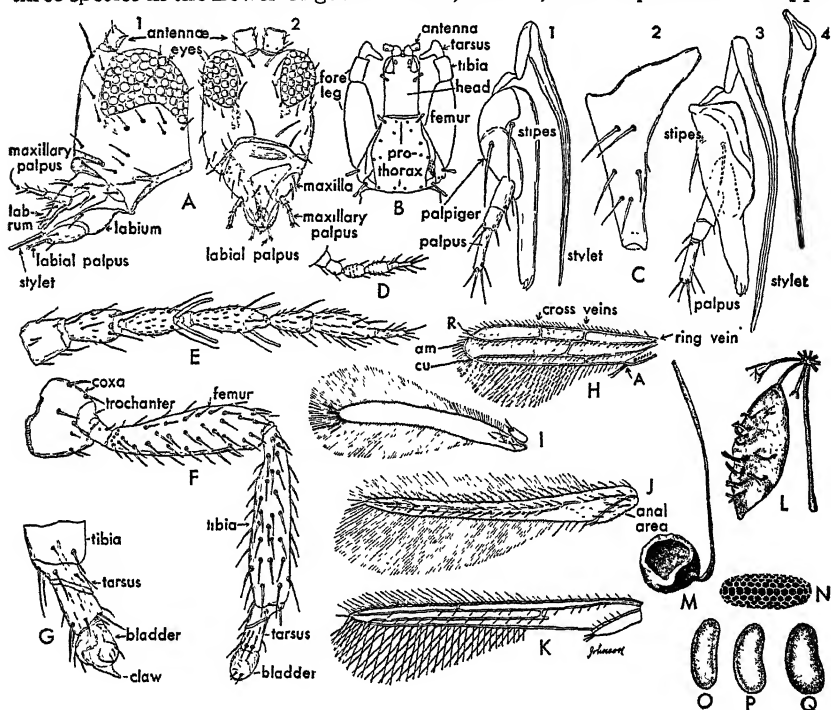


FIG. 87. THYSANOPTERA or thrips. Various structures. A, head, C, mouth parts, and F, hind leg of *Tæniothrips atratus* Haliday (after Melis); B, head and prothorax and M, gall on acacia of *Kladothrips augonsoxos* Moulton in Australia (after Moulton); D, antenna of 2nd instar larva of *Frankliniella insularis* (Franklin); E, antenna, G, tarsus, J, fore wing, and P, egg of the pear thrips, *Tæniothrips inconsequens* (Uzel) (D, E, G, after Melis; J, after Foster and Jones); H, fore wing of *Olothrips kelloggii* Moulton (after Moulton); I, fore wing of the olive thrips, *Liothrips oleæ* (Costa) (after Melis); K, fore wing of *Anaphothrips enceliæ* Moulton (after Moulton); L, galls of *Smerinthothrips heptapleuricola* Takahashi on the leaves of *Heptapleurum* in Japan (after Takahashi); N, egg of *Cryptothrips floridensis* Watson (after Yothers and Mason); O, egg of the apterous wheat thrips, *Prosopothrips cognatus* Hood (after Kelly); Q, egg of the bean thrips, *Hercothrips fasciatus* (Pergande) (after Russell).

Oligocene of Rott, Germany. The genera include *Lithadothrips* Scudder, *Palæothrips* Scudder, *Melanothrips* Haliday, and *Thrips* Linnæus. Species of *Phlæothrips* Haliday of the family PHLÆOTHIRIPIDÆ have been found as follows: one species in Upper Oligocene of Rott, Germany; two in African Copal; one in Indian Copal; three in Baltic Amber; one in Lower Oligocene of Aix, France; two in Upper Miocene of Eningen, Germany; and three uncertain species in Copal (Schröder, 1925).

Thrips are widely distributed throughout the tropical and temperate regions and may be found wherever plants occur except in the polar regions. Although about 350 genera and 2,500 species have been described, there remain perhaps as many or even more awaiting discovery and investigation.

COLLECTING, PRESERVING, AND MOUNTING

As has already been stated, thrips abound in flowers, on foliage, fruits, bark, fungi, mosses, and other forms of vegetable life; and in debris, decayed vegetation, and in the soil. They may be restricted to a genus or family of plants or may be general feeders. It is therefore important to know the hosts of every species taken, which means that much of the collecting must be very carefully done although beating and sweeping may be resorted to on many specific plants. Traps may be employed in capturing debris- and soil-inhabiting forms.

Specimens may be preserved in 80 per cent alcohol or other liquid preservative.

For microscopical study the specimens may be prepared by removing body contents in a 5 or 10 per cent solution of KOH or NaOH or in lactic acid; by dehydrating in alcohol; clearing in clove oil, cedarwood oil, xylol, or similar materials, and mounting directly into euparal or canada balsam.

Very good mounts may also be obtained by placing fresh material directly in Berlese, Faure, or similar media, heating at 100°F for 1 hr., and ringing with a suitable cement.

Immature forms and transparent specimens may be greatly improved for study by staining in fuchsin, fast green, and other permanent stains.

CLASSIFICATION

A. Suborder TEREBRANTIA Haliday 1836

I. Superfamily ÆOLOTHRIPOIDEA Hood 1915

1. Family ÆOLOTHRIPIDÆ Uzel 1895 (COLEOPTERATIDÆ Beach 1896)
2. " OROTHRIPIDÆ Bagnall 1926
3. " MELANTHRIPIDÆ Bagnall 1926 ¹
4. " DACTULIOTHRIPIDÆ Moulton 1931
5. " FRANKLINOTHRIPIDÆ Bagnall 1926

II. Superfamily MEROTHRIPPOIDEA Bagnall 1930

6. Family MEROTHRIPIDÆ Hood 1914

III. Superfamily THRIPOIDEA Hood 1915

7. Family HETEROTHRIPIDÆ Bagnall 1912 ²
8. " HEMITHRIPIDÆ Bagnall 1930 ³
9. " CERATOTHRIPIDÆ Bagnall 1912
10. " PANCHÆOTHRIPIDÆ Bagnall 1912
11. " THRIPIDÆ Stephens 1829, Uzel 1895 (STENOPTERIDÆ Beach 1896)

¹ Placed in the superfamily MELANTHRIPPOIDEA by Bagnall 1930.

² Placed in the superfamily HETEROTHRIPPOIDEA by Bagnall 1930.

³ Placed in the superfamily HEMITHRIPPOIDEA by Bagnall 1930.

B. Suborder TUBULIFERA Haliday 1836

IV. Superfamily PHLÆOTHRIPOIDEA Uzel 1895

- 12. Family PYGOTHRIPIDÆ Hood 1915
- 13. " ECACANTHOTHRIPIDÆ Bagnall 1912
- 14. " EUPATHITHRIPIDÆ Bagnall 1915
- 15. " PHLÆOTHRIPOIDEA Uzel 1895
- 16. " CHIROTHRIPOIDIDÆ Bagnall 1912
- 17. " HYSTRICOTHRIPIDÆ Karny 1913
- 18. " IDOLOTHRIPOIDÆ Bagnall 1908
- 19. " MEGATHRIPOIDÆ Karny 1913

V. Superfamily UROTHRIPOIDEA Hood 1915

- 20. Family UROTHRIPOIDÆ Bagnall 1909

C. Unassigned Families

- 21. Family MYMAROTHRIPIDÆ Bagnall 1930
- 22. " OPADOTHRIPIDÆ Bagnall 1930 (mostly fossil)
- 23. " STENUROTHRIPOIDÆ Bagnall 1930 (fossil)

KEY TO SUBORDERS ¹

- 1. Female with a saw-like ovipositor; last abdominal segment of female conical, that of the male broadly rounded; wings usually present, the front pair largest, usually with well-developed veins and always with at least the costa and one longitudinal vein extending from the base to the apex; wing membrane with microscopic hairs. **TEREBRANTIA**
- 2. Female without a modified ovipositor; the last segment of the abdomen tubular in both sexes; wings absent or present, both pairs similar in structure, the front wings with only a median longitudinal vein which does not extend to the tip of the wings; wing membrane without microscopic hairs **TUBULIFERA** p. 259

A. Suborder TEREBRANTIA ² Haliday 1836

(Ter'e-bran'ti-a, from the Latin *terebrā*, a borer; referring to the ovipositor for inserting eggs into the tissues of plants.)

Female with a saw-like ovipositor; terminal abdominal segment divided longitudinally on the venter and conical; male with the terminal abdominal segment broadly rounded; wings usually present, fore pair much the larger and normally with well-developed veins consisting of a marginal vein and at least one cross vein extending to the front margin; wing membrane with microtrichia.

KEY TO SUPERFAMILIES

- 1. Ovipositor well developed 2
- Ovipositor much reduced and probably functionless; pronotum with dorsal longitudinal sutures; wing surface smooth; antennæ monili-

¹ The keys used for this order are adapted from those of Hood, Karny, Priesner, Brues and Melander, and other specialists.

² This term has also been used to designate a division of the HYMENOPTERA, including the CHRYSIDIDÆ.

form, eight-segmented, without endstylus; fore and hind femora greatly thickened. Nearctic and Neotropical. (Large-legged Thrips.)

MEROTHRIPOIDEA

2. Ovipositor curved upwards **ÆOLOTHRIPOIDEA**
Ovipositor curved downwards **THRIPOIDEA**

I. Superfamily ÆOLOTHRIPOIDEA Hood 1915

KEY TO IMPORTANT FAMILIES

1. Labial palpi with fewer segments than maxillary palpi; all segments of antennæ freely movable 2
Labial palpi with same number of segments or one more segment than maxillary palpi; terminal three to five segments of antennæ closely united and not freely movable 3
2. Maxillary palpi seven- or eight-segmented; labial palpi three- to five-segmented. Nearctic **OROTHRIPIDÆ**
Maxillary palpi three-segmented; labial palpi two-segmented. Widespread. (Black Thrips.) **MELANTHRIPIDÆ**
3. Antennæ short, segmentation regular, segments III and IV with elongated sensory areas; wings broad; fore wings with distinct cross veins; with three well-developed ocelli. Widespread. (Broad-winged Thrips.) **ÆOLOTHRIPIDÆ**
Antennæ very long and slender, segment III as long as head, segments III and IV without elongated sensory areas; fore wings slender, without cross veins; front ocellus rudimentary or absent. Nearctic and Ethiopian **FRANKLINOTHRIPIDÆ**

Family ÆOLOTHRIPIDÆ Uzel 1895 (Æ'o-lo-thrip'i-dæ, from the Greek *αἰδῶλος*, changeful, streaked, + *θρίψ*, a woodworm; meaning streaked or bizarre thrips). The Broad-winged Thrips.

Body not depressed; antennæ nine-segmented; fore wings broad, rounded apically, and with ring veins and cross veins; ovipositor upcurved.

A small family of predacious species which is widely distributed in various parts of the world. The adults are mostly dark brown and black, often with whitish or dusky mottled wings.

The best known species is the striped or banded thrips, *Æolothrips fasciatus* (Linn.), 1.6 mm. long, yellowish to dark brown, with banded wings. It occurs on a wide variety of small plants, shrubs, and trees and is predacious upon other species of thrips and upon aphids and other small insects and mites. It occurs in Europe, North America, northern Asia, Africa, and Hawaii.

III. Superfamily THRIPOIDEA Hood 1915

KEY TO IMPORTANT FAMILIES

1. Antennæ nine-segmented, sometimes apparently 10-segmented, without apical style. 2
Antennæ six- to eight-segmented, sometimes apparently nine-segmented because of a suture dividing second segment, usually with one- or

- two-segmented apical style, segments III and IV not enlarged or conical 3
2. Antennal segment III cylindrical and not conical . . . **HEMITHRIPIDÆ**
 Antennal segments III and IV enlarged and conical, without sense cone but with sense bands at end; second tarsal segment of fore tarsus with claw-like appendage at base **HETEROTHRIPIDÆ**
3. Antennal segment VI well developed and usually as large or larger than V 4
 Antennal segments VI and VII very small and style-like and much smaller than V. Palæarctic **CERATOTHRIPIDÆ**
4. Last abdominal segment in female cylindrical, heavily chitinated, segments IX and X with very long, stout, spine-like bristles. Oriental. (Bristle Thrips.) **PANCHÆTOTHRIPIDÆ**
 Last abdominal segment of female conical and poorly sclerotized — rarely more sclerotized than preceding segments — segments IX and X without spine-like bristles; antennal segment VI usually the largest. Cosmopolitan **THRIPIDÆ**

Family THRIPIDÆ Stephens 1829 (Thrip'i-dæ, from the Greek *θρίψ*, a wood-worm; or thrips). Thrips.

The largest and most important injurious family of thrips. The body is somewhat depressed; antennæ six- to eight-segmented, with one- or two-segmented terminal style, sensoria on segment III and also usually on segment IV, and segment VI enlarged; wings absent or present, usually narrow and pointed apically; ovipositor normally well developed and downcurved; bristles on abdominal segments IX and X not particularly prominent.

The members of this family are often exceedingly abundant and occur upon many types of vegetation. They feed upon the leaves, fruits, buds, and flowers and may cause serious crop losses.

The family is composed of no less than 33 genera and 200 species. The important genera are *Thrips* Linn., *Heliothrips* Haliday, *Limothrips* Haliday, *Teniothrips* Serville, *Frankliniella* Karny, *Scolothrips* Hinds, *Drepanothrips* Uzel, *Scirtothrips* Shull, and *Hercothrips* Hood.

Some of the more important species may be mentioned, as follows:

The tobacco or onion thrips, *Thrips tabaci* Lindeman, is a pale-yellowish or brown species 1.0–1.2 mm. long, which is a serious pest of beans, onions, tobacco, cabbage, and a great many other cultivated and wild plants in Europe, Asia, Australia, Hawaii, and North America. It has also been carried to many other parts of the world. It often swarms in immense numbers. The larvæ and the adults may bite even human beings. It transmits the virus that causes spotted wilt disease of tomatoes and many other host plants and yellow spot disease of pineapples.

The European thrips, *Thrips physapus* Linn., is 1.0–1.3 mm. long and dark golden in color. It is a very common species in Europe and also occurs in North America. It may be very abundant in flowers and on ornamental and fruit trees.

The blossom thrips, *Thrips imaginis* Bagnall, is a pale-yellow and brown species that greatly resembles the tobacco thrips in color and size. It is a native of Australia which appears at times in immense numbers and flies in swarms on hot days so as to "constitute a plague" and to become most annoying to man. It infests a wide variety of plants and has been specially injurious to the blossoms of roses, apples, pears, berries, and other fruits in which the eggs are inserted. It also attacks the stems of potatoes and other plants but is essentially

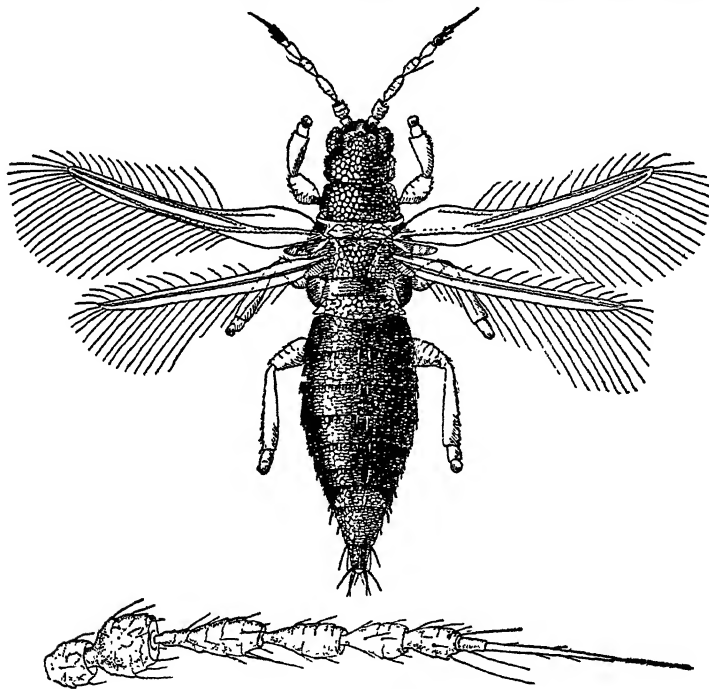


FIG. 88. The Greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché), a widely distributed tropical and subtropical species. (After Russell from *Insects of Western North America*.)

a blossom-infesting species. It has several generations a year. Pupation occurs in the soil.

The greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché), is a dark-brown species 1.0–1.2 mm. long with conspicuous reticulations on the body and parts of the legs. It is probably a tropical and semitropical species which lives out of doors in warm and temperate regions and in greenhouses in less favorable areas. It is almost cosmopolitan in distribution and is known to occur in Europe, Asia, North America, the South Sea Islands, and Australia. Males are unknown.

The corn thrips, *Limothrips cerealium* Haliday, is 1.2–1.4 mm. long, dark brown to black, with pale markings and distinct surface reticulations. This is a

common and often very abundant species in Europe and swarms in hot weather during the harvest season, when it enters houses and crawls over and greatly annoys and even bites the exposed parts of the bodies of workmen and bathers, causing a skin itch. In Germany it is called "thunderstorm fly." This species also occurs in North America.

The pear thrips, *Teniothrips inconsequens* (Uzel), is a brown species with grayish wings and a body length of 1.2–1.3 mm. The adults, emerging in February and March, attack the buds, blossoms, leaves, and young fruits of plums, cherries, pears, and other plants and oviposit in the petioles of the leaves and fruits. The young are pale whitish and are commonly called "white thrips." They cease feeding in May and June, drop to the ground, and form a cell in the soil from 4 to 8 in. beneath the surface. Aestivation occurs here until October and November when pupation and hibernation takes place, the adults emerging in the following spring. Thus 7 or 8 months of the year are passed in an inactive condition in the soil. The species occurs in Europe and in North and South America.

The gladiolus thrips, *Teniothrips simplex* Morison (= *gladioli* Moulton and Steinweden), is similar to the preceding species. It seriously infests gladiolus plants, flowers, and corms in North America. It has been widely distributed by commerce.

The wheat thrips, *Frankliniella tritici* (Fitch), a slender, pale-yellow and orange species 1.23 mm. long, is an omnivorous feeder on grasses, weeds, field and truck crops, cereals, ornamental shrubs, and trees, and is a serious pest to many of these. It is widely distributed in North America.

The black carnation thrips, *Frankliniella insularis* (Franklin), is a dark-brown or blackish species, 1.0–1.3 mm. long, which has a wide distribution since it occurs in South Australia, the southern part of the United States, Mexico, Central America, the West Indies, and the northern part of South America. It attacks a wide variety of plants and is mainly a flower-infesting species. The western flower thrips, *Frankliniella occidentalis* Pergande, transmits spotted wilt of tomatoes and other hosts in California, and *F. nigripes* Girault (*F. lycopersici* Andrewartha) plays a similar role in Australia.

The six-spotted thrips, *Scolothrips sexmaculatus* (Pergande), is a minute yellow species with three dark spots on each fore wing and is only about 0.83 mm. long. It is of interest because of its predatory habits in feeding upon plant-infesting mites of the genera *Tetranychus*, *Bryobia*, and *Paratetranychus*, and is therefore a beneficial species. It is recorded in Europe, North America, Hawaii, and the Philippine Islands. *S. acriphagus* Yakhontov is an important predator on the mite *Tetranychus telarius* (Linn.) on cotton in central Asia and has often been mistaken for the preceding species.

Two species of citrus thrips are important: the citrus thrips, *Scirtothrips citri* (Moulton), of Arizona and California, and the South African citrus thrips, *Scirtothrips aurantii* Faure, of South Rhodesia and the Union of South Africa. Both species do considerable injury to the young foliage and to the fruit of citrus trees.

B. Suborder TUBULIFERA¹ Haliday 1836

(Tu'bu-lif'e-ra, from the Latin *tubus*, a tube; referring to the tubular terminal abdominal segment.)

The members of this suborder are characterized by the presence or absence of wings, the surface of which are without microtrichia and the fore pair of which are veinless or with a single abbreviated median vein; by the tubular terminal abdominal segment; and by the absence of an ovipositor.

For the most part the species are predacious upon other small insects and mites and feed upon exudations of plants, dead and decayed vegetable material, and fungi. A number of species, however, are phytophagous and do considerable injury to certain cultivated plants.

KEY TO SUPERFAMILIES

1. Maxillary palpi two-segmented; antennæ seven- or eight-segmented, usually eight-segmented; middle coxæ farther apart than other pairs
PHLÆOTHRIPOIDEA
- Maxillary palpi one-segmented; antennæ four- to seven-segmented;
 hind coxæ farther apart than other pairs . . . UROTHRIPOIDEA

IV. Superfamily PHLÆOTHRIPOIDEA Karny 1907

KEY TO IMPORTANT FAMILIES

1. Abdominal segment VIII normal and without peg-like projections along the posterior margin 2
 Abdominal segment VIII with long peg-like projections along the posterior margin; last abdominal segment very short and stout
CHIROTHRIPOIDIDÆ
2. Head not produced anteriorly in front of eyes; vertex not sharply conical and rarely overhanging base of antennæ 3
 Head somewhat produced in front of eyes; vertex conical and usually conspicuously overhanging base of antennæ and with front ocellus at extremity; usually with strong bristle in front of eye IDOLOTHRIPIDÆ p. 261
3. Male with stout tubular projection on each side of abdominal segment VI. (Large Thrips.) MEGATHRIPIDÆ
 Male without lateral projections on abdominal segment VI 4
4. Last abdominal segment greatly elongated, three or four times as long as the head or about as long as the remaining abdominal segments together HYSTRICOTHRIPIDÆ
 Last abdominal segment much shorter than the combined lengths of remaining abdominal segments 5

¹ This term is also employed for a tribe of the order HYMENOPTERA comprising the family CHRYSIDIDÆ and sometimes including also the family SERPHIDÆ.

5. Last abdominal segment not entirely tubular, short, swollen, rounded on sides; preceding abdominal segments transversely linear. Australian **PYGOTHRIPIDÆ**
 Last abdominal segment tubular, narrowed apically; preceding segments not transversely linear 6
6. Sense organs on antennal segment III in the form of a conspicuous crest-like ring or large cones at apex. Oriental **ECACANTHOTHRIPIDÆ**
 Sense organs on antennal segment III similar to those on other segments 7
7. Sensory cones on antennæ usually long and pointed, each with accessory cone or long, slender bristle; cone-bearing segments greatly swollen; eyes conspicuously large, contiguous **EUPATHITHRIPIDÆ**
 Sensory cones of antennæ not unusually developed; eyes small and rarely contiguous. Cosmopolitan **PHLEOTHRIPIDÆ**

Family PHLEOTHRIPIDÆ Uzel 1895 (Phlœ'o-thrip'i-dæ, from the Greek *φλοιός*, smooth outside surface, exoskeleton, + *thrips*; referring to the integument).

This is an important and widely distributed family which consists of many genera and several hundred species. The members are mostly dark brown and black, often with whitish, dusky, or mottled wings. The head is rounded in front; sensory antennal cones present; antennal segment III largest; abdominal segment IX a little wider than long; and the last abdominal segment somewhat narrowed posteriorly and not greatly lengthened. There are about 200 species in North America. The important genera are: *Cryptothrips* Uzel, *Haplothrips* Serville, *Hoplandrothrips* Hood, *Hoplothrips* Serville, *Leptothrips* Uzel, *Liothrips* Uzel, *Phlæothrips* Haliday, *Rhynchothrips* Hood, *Trichothrips* Uzel, and *Zygothrips* Uzel.

Among the many interesting species may be mentioned the statice thrips, *Haplothrips leucanthemi* (Schrank), 1.5–1.8 mm. long and black with yellow markings. It is a European species introduced into North America and is a plant-infesting species and a pest of ornamentals, field crops, truck crops, and fruit trees. It has been particularly destructive to the clover-seed crop in parts of western North America. *H. aculeatus* Fab. and *H. trilici* Kurdjumov are pests of grain and many other plants in southern Europe.

The lily thrips, *Liothrips vaneckei* Priesner, is a dark-brown or blackish species 2.0–2.3 mm. long which infests lilies in Europe and greatly injures the bulbs. It has been distributed throughout much of Europe and carried to North America by means of lily bulbs. The olive thrips, *Liothrips oleæ* (Costa), a black species 2–3 mm. long, is a serious pest of olives in the Mediterranean region. *L. urichi* Karny has been employed in an attempt to control a noxious weed, *Clidemia hirta*, in Fiji.

The Christmasberry thrips, *Rhynchothrips ilex* (Moulton) (*Liothrips*), is a common species in California and attacks the growing tips of the native Christmasberry, *Photinia*.

The black hunter, *Leptothrips mali* (Fitch), is one of many predacious species. It ranges throughout much of North America.

Phlaothrips oryzae Matsumura feeds on rice and other cereal crops, and *P. pubicornis* Mats. infests sugar cane in Japan. A closely related species, *Onychothrips tepperi* (Uzel) (*Phlaothrips*) forms galls¹ on *Acacia aneura* in Australia.

The mullein thrips, *Neoheegeria verbasci* (Osborn), is a black species common on mullein in Europe and North America.

Family IDOLOTHRIPIDÆ Bagnall 1908 (I-dol'o-thrip'i-dæ, from the Greek εἶδωλον, a phantom, + *thrips*; referring to the striking appearance of these thrips).

The most interesting member in this family and one of the most remarkable and probably the largest species in the order is the giant thrips, *Acanthinothrips spectrum* (Haliday) (*Idolothrips*), which is a black species 10–14 mm. long that was discovered in Australia by Charles Darwin in 1836. It is a slow-moving species living and feeding upon the dead and moist leaves of eucalyptus on the ground.

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CHAPTER XXV

22. Order HEMIPTERA¹ Linnæus 1758

(He-mip'ter-a, from the Greek prefix ἡμι, half, + πτερά, wings; from the character of the partly thickened and partly membranous fore wings or hemelytra.) German, Wanzen.

Land and Water Bugs, Cicadas, Treehoppers, Leafhoppers, Spittlebugs, Lanternflies, Psyllids, Aphids, Whiteflies, Scale Insects.

Minute to large, oval or elongate, frequently flattened, heterogenous, phytophagous and predacious, terrestrial and aquatic insects with simple metamorphosis and piercing and sucking mouth parts; head free, usually prognathous or rarely hypognathous; antennæ two- to 10- or rarely 25-segmented; eyes large; ocelli present or absent; labium modified into a short or long, curved or straight, simple or segmented rostrum, beak, or proboscis; palpi atrophied; wings present or absent, two pairs (one pair in male COCCOIDEA), long or short; hemelytra, or fore pair, usually thickened basally and membranous apically in HETEROPTERA and usually wholly membranous in HOMOPTERA; legs for walking, running, jumping, digging, grasping prey, and swimming (absent in certain COCCOIDEA); cylindrical or flattened, with one- to three-segmented tarsi, one or two claws, and with or without arolia or empodia; abdomen with few to 10 segments, the first segment greatly reduced or apparently wanting; cerci absent; anal respiratory filaments present in some aquatic forms and anal filaments in male coccids.

The members of this important order are a heterogenous lot difficult to characterize under a single order and yet held together by a chain of remarkably similar links. They are commonly referred to as bugs and include such notorious members as the bedbugs, age-long tormentors of the human race, and countless numbers of economic species attacking man, domesticated and wild

¹ The order HEMIPTERA was established by Linnæus in 1735 to include insects with wings but without wing covers, except in a few cases. In it were placed such widely separated genera as *Cimex*, *Nolonecta*, *Gryllus*, *Lampyrus*, and *Formica*, representatives of four different orders. In 1758 he restricted the order to insects now generally thought to belong in it but also included the THYSANOPTERA. In 1810 Latreille divided the order into two suborders, HETEROPTERA and HOMOPTERA, which have been generally accepted up to this time. There has been, however, a lack of uniformity among entomologists in the usage of the order and subordinate names. MacLeay in 1821 was probably the first to raise the HOMOPTERA to order rank, and in recent years this has been a common practice among systematists and textbook writers. More recent evidence of the close relationship of the two groups from the study of fossils and the anatomy and biology of the insects points strongly to a continued acceptance of Latreille's views. Supporting them are such modern authorities as Van Duzee 1917, Butler 1923, Parshley 1925, Tillyard 1925, N. D. Riley 1931, Imms 1934, Hedicke 1935, Haupt 1935, Perrier 1935. Those separating them into the HEMIPTERA and HOMOPTERA are Comstock 1924, Brues and Melander 1932. Those using the order names HETEROPTERA and HOMOPTERA are Schröder 1925, Weber 1933, Folsom and Wardle 1934, Lutz 1935.

This chapter has been read by R. L. Usinger, who has kindly made many helpful suggestions.

animals and fowls, and agricultural crops. A few are helpful in destroying injurious mites and other insects. They vary in size from the minute phylloxeras, scarcely visible to the unaided eye, to the giant water bugs attaining a length of over $4\frac{1}{2}$ in. In shape they are equally variable. A great many are shield-shaped or oval and flattened; some are robust, globular, hemispherical, or disk-like; and still others are elongated, slender, cylindrical, and thread-like. The appendages are often modified to accentuate the form.

The range and combinations of colors are almost inexhaustible. In the cooler regions, colors for the most part are dull and uninteresting, but in the

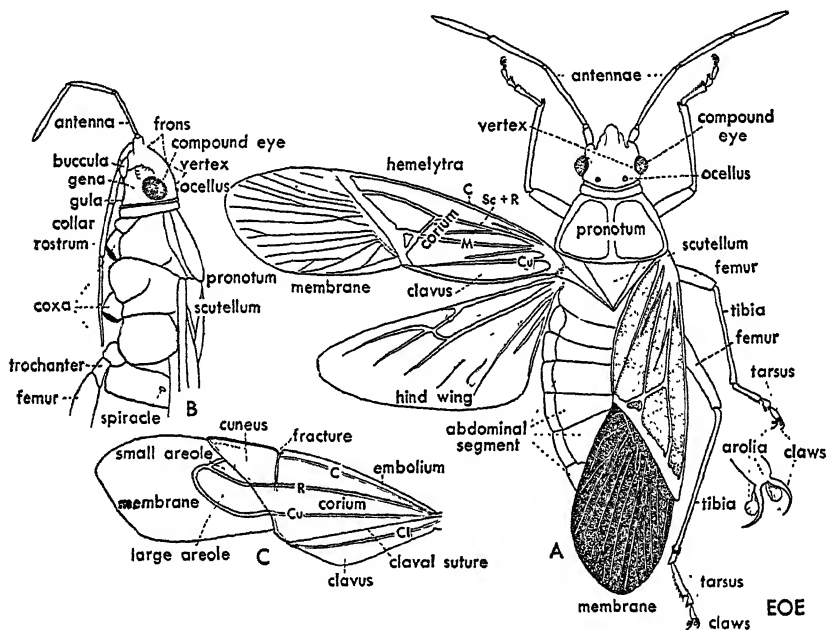


FIG. 89. External anatomy of HEMIPTERA. A, box-elder bug, *Leptocoris trivittatus* (Say), with the left hemelytron and wing spread; B, same, side view of head and thorax; C, hemelytron of the tarnished plant bug, *Lygus pratensis* (Linn.) (From *Insects of Western North America*.)

warmer temperate zones, and especially in the tropics, they are brilliant and striking beyond description, with opaque, transparent, and metallic hues.

The biology will be discussed under the suborders, families, and species. Suffice it here to say that the metamorphosis, though generally simple, becomes quite complex in the males of the coccids, and the life histories are exceedingly complicated in the aphids, phylloxerids, and adelgids. Bisexuality and sexual dimorphism are the rule, though parthenogenesis is very common. True sexes are unknown in certain species of aphids in some regions.

The great majority of the species are phytophagous and feed upon the juices

of living plants, causing great losses to agricultural crops. They not only destroy the plants by excessive feeding but inject into the tissues toxins and virus diseases that are often very destructive to plant life.

A considerable number are predacious upon many small animals and other insects, and attack warm-blooded birds and mammals, including man. These forms may also transmit organisms that cause diseases and death to the hosts.

The oldest fossil ancestors of the HEMIPTERA are the members of the order PROTOHEMIPTERA Handlirsch characterized by small head, pronotal expansions, suctorial mouth parts, and complicated, netted wing venation. The genera *Eugereon* Dohrn from the Lower Permian of Germany and *Mesotitan* Tillyard from Middle and Upper Trias of New South Wales, Australia, are among the largest fossil insects known, the former having an estimated wing expanse of 160 mm.

In the Lower Permian of Kansas the homopterous members of the archaic family ARCHESCYTINIDÆ occur. In wing venation these ancestors are also allied to the PSOCOPTERA (Imms, 1937). In the Upper Permian of Belmont, Australia, homopterous forms of the family SCYTINOPTERIDÆ Handlirsch were found. The latter family and the family PROBOLIDÆ were also taken in Russia by Martynov (1928). HETEROPTERA appear in the Trias at Ipswich, New South Wales, in the families DUNSTANIIDÆ, related to the PENTATOMIDÆ, and TRIASSOCORIDÆ, having affinities with the NOTONECTIDÆ. In the Trias of Australia the HOMOPTERA were also represented by the MESOGEREONIDÆ, ancestors of the CICADIDÆ. (Tillyard, 1926).

In the Jurassic remains they are quite common, and in the sediments and amber of the Tertiary they are often abundant.

The HEMIPTERA is a relatively large order consisting of approximately 150 families, 1,000 genera, and 48,000 species. The members occur throughout the world except in the polar areas. Members of certain families are most abundant in the tropics, while others reach their greatest development in the temperate regions. Individuals of a given species of HOMOPTERA may attain inconceivable numbers and overrun the food plants in a small or large area.

KEY TO SUBORDERS

1. Base of rostrum usually not touching anterior coxæ; gular region ¹ usually well developed, long; pronotum large; fore wings usually thickened basally and membranous apically, hind wings membranous, both pairs folded flat over the back with apices overlapping; tarsi normally three-segmented HETEROPTERA p. 266
2. Base of rostrum usually touching anterior coxæ; gular region wanting, short, or membranous; pronotum small; wings usually of same texture throughout (the fore pair rarely thickened and pigmented in CICADELLIDÆ, folded roof-like over the back; tarsi one- to three-segmented HOMOPTERA p. 307

¹ Snodgrass (1935) calls this the hypostomal bridge.

Suborder HETEROPTERA Latreille 1810

(Het'er-op'ter-a, from the Greek ἕτερος, other, different, + πτερά, wings; referring to the marked differences between the fore and hind pairs of wings.) German, Wanzen.

Bugs.

IMPORTANT EXTERNAL ANATOMICAL CHARACTERS

Size — small to very large insects, up to 100 mm. or nearly 4 in.

Shape — slender and subcylindrical or more commonly rounded, oval, broadly elongate and flattened, or shield-shaped.

Integument — usually hard and coriaceous or leathery and parchment-like; pigmented; punctured and rugose, or smooth and shiny; rarely hairy or spiny.

Color — variable from dull and drab to a great variety of brilliant colors, some of which are metallic. Some species are varicolored and bizarre.

Head — variable in form and saturation; usually prognathous, but hypognathous in some forms; generally free and often with a neck-like region.

Compound eyes — large and prominent, many-faceted, widely separated or small, and absent.

Ocelli — usually present and two in number, rarely absent. Both compound eyes and ocelli absent in family POLYCTENIDÆ.

Antennæ — usually present and well developed or rarely atrophied or absent; inserted above or below the eyes; usually four- or five-segmented; segments simple or ornamented with enlargements; free or fitting into a groove in the head or prothorax.

Mouth parts — modified for piercing and sucking fluids from plants and animals. *Clypeus* — dorsal, small and poorly developed except anteriorly in the CIMICIDÆ and POLYCTENIDÆ. *Labrum* — short, triangular, slender, and sharply pointed apically or broad and flap-like; covering bases of mouth parts. *Mandibles* — the anterior outer pair of stylets which are bristle-like and may be serrated apically. *Maxillæ* — the maxillary, posterior or inner pair of stylets arising from a basal sclerite or the fused cardo and stipes; bristle-like and two-grooved along inner margin so as to form two capillary tubes — a dorsal suction tube and a ventral salivary ejection tube. *Maxillary palpi* — vestigial or usually absent. *Labium*, *rostrum*, or *proboscis* — very small and simple to greatly enlarged into a short or long, rigid, curved or straight, three- or four-segmented sucking tube with a dorsal channel enclosing the mandibular and maxillary stylets; folded between the legs along the venter at rest. *Gula* — a large chitinated ventral area behind the base of the labium. *Genæ* — lateral ventral areas at the sides of the head behind the eyes.

Thorax — compact and closely fused. *Prothorax* — small or large, sometimes long and neck-like, and may have lateral prolongations or horns. *Meso-* and *metathorax* — complex, with many sclerites. *Scutellum* — most important

division of the mesonotum, often very large and may even cover the abdomen. *Metanotum* — reduced or well developed.

Legs — variable and adapted for crawling, walking, jumping, grasping prey, and swimming. *Femora* — frequently greatly enlarged; smooth or spined. *Tibiae* — cylindrical or flattened, plain, swollen, or with leaf-like enlargements, and with swimming hairs in aquatic forms; often hairy or spined, but usually without apical spurs. *Tarsi* — normally three-segmented, rarely one- or two-segmented and heteromerous; sometimes greatly reduced. *Claws* — apical or ante-apical with or without arolia or empodia.

Wings — adults may be wholly apterous, brachypterous, or have rudimentary wings; two pairs, usually folded flat over the dorsum with the apical portions overlapping; fore wings or *hemelytra* with basal portions thickened or coriaceous and divided into two areas: the *clavus* and *corium* (from the *corium* may also be separated the narrow *embolium* and the wedge-shaped *cuneus*) and with the apices membranous, hind wings wholly membranous; veins distinct, obscure, and often few or almost entirely wanting. In some species (TINGIDÆ) the membranous areas are indistinct and in others (ENICOCEPHALIDÆ) the wings are wholly membranous.

Spiracles—two pairs, one each on the meso- and metathorax.

Abdomen — usually rather wide, but long and slender in some groups; nine- to 11-segmented, usually 10-segmented.

Spiracles — usually a pair on each of the first seven or eight abdominal segments; most often on the ventral sides.

Ovipositor — well developed in the aquatic families NEPIDÆ and NOTONECTIDÆ and such terrestrial families as LYGÆIDÆ, some ANTHOCORIDÆ, and others.

Sound-producing organs —

1. Prosternal cross-striated furrow scraped by rough apex of the rostrum in REDUVIIDÆ and PHYMATIDÆ.
2. Lateral strigose areas on abdominal segments IV and V rubbed by extensions on the inner sides of hind tibiae.
3. Tarsal and femoral denticles contacted in a right to left manner and vice versa.
4. Coxal rasps functioning against similar areas on the margins of the coxal cavities in the genus *Ranatra*.
5. File at base of abdomen contacting comb on venter of wing bases in certain species of *Tessaratoma*.

IMPORTANT INTERNAL ANATOMICAL CHARACTERS

Tentorium — absent (present in HOMOPTERA)

Digestive System.

Alimentary canal — complex.

Mouth — no true mouth; entrance to the digestive tract through suction canal at base of stylets and pharyngeal duct.

Pharynx — chief suction organ.

Gustatory organ — present in most forms — sensory cells communicating with pharyngeal duct.

Mid-intestine or ventriculus — often divided into (1) anterior sac-like pouch; (2) tubular section; (3) enlarged ovoid chamber; (4) narrower tubular portion which is absent if there are no gastric cæca.

Gastric cæca — present if narrower tubular portion is present; bacteria reservoir; variable in number from none or few to several hundred.

Malpighian tubules — usually four but fewer occur.

Salivary glands — two- or many-lobed thoracic glands which may be very large; piliform or sac-like accessory glands; ducts unite into single canal emptying into salivary pump.

Odoriferous glands — characteristic of many species of bugs. Openings located either laterally or at the middle of the metathorax near hind coxæ. Situated on the anterior dorsal margins of abdominal segments IV to VI in the nymphs.

Circulatory System. Not greatly specialized.

Heart — five-chambered.

Pulsatile organs — present in legs of aquatic bugs.

Respiratory System. Well-developed system; tracheal trunks large.

Spiracles — variable in form and protective mechanisms; one pair on mesothorax, one pair on the metathorax, and seven to eight pairs on abdominal segments I to VII or I to VIII; usually located ventrally on the sides of the abdomen.

Nervous System. A tendency towards condensation of the nervous centers; according to Raandt (1878), (Imms, 1934), there may be: (1) one center in *Hydrometra*; (2) two ganglia fused together in *NEPIDÆ*; (3) three ganglia: infra-oesophageal, first thoracic, and abdominal ganglia in segments II and III fused together.

Reproductive System. Variable, especially in the male.

Female — *ovarioles* — vary in number from four to seven.

Spermatheca — usually present and complex, may be a single organ or small paired organs.

Accessory glands — globular or tubular; two or three in number.

Berlese organ — a copulatory pouch to receive spermatozoa and pass them on to the ova in the *CIMICIDÆ*.

Viviparity — pseudo-placental organs formed in the *POLYCTENIDÆ*.

Male — *testes* — consisting of six follicles in a scrotum. Very little information available concerning the male organs.

CLASSIFICATION ¹

Suborder HETEROPTERA Latreille 1810

SERIES I. GYMNOCERATA (Terrestrial and Subaquatic Forms)

Section GEOCORISÆ

- | | |
|--------------------------------|---|
| 1. Family PLATASPIDIDÆ | 16. Family PIESMIDÆ |
| 2. " PODOPIDÆ (GRAPHOSOMATIDÆ) | 17. " THAUMASTOTHERIIDÆ (THAUMASTOCORIDÆ) |
| 3. " CYDNIDÆ | 18. " ENICOCEPHALIDÆ |
| 4. " SCUTELLERIDÆ | 19. " PHYMATIDÆ |
| 5. " PENTATOMIDÆ | 20. " REDUVIIDÆ |
| 6. " COREIDÆ | 21. " PLOIARIIDÆ |
| 7. " CORIZIDÆ | 22. " NABIDÆ |
| 8. " ALYDIDÆ | 23. " POLYCTENIDÆ |
| 9. " ARADIDÆ | 24. " CIMICIDÆ |
| 10. " DYSODIIDÆ | 25. " ANTHOCORIDÆ |
| 11. " TERMITAPHIDIDÆ | 26. " MICROPHYSIDÆ |
| 12. " NEIDIDÆ (BERYTIDÆ) | 27. " MIRIDÆ (CAPSIDÆ) |
| 13. " LYGÆIDÆ | 28. " CRYPTOSTEMMATIDÆ (CERATOCOMBIDÆ, DIPSOCORIDÆ) |
| 14. " PYRRHOCORIDÆ | |
| 15. " TINGIDÆ | 29. " SALDIDÆ |

Section AMPHIBICORISÆ

- | | |
|--------------------|--------------------|
| 30. Family HEBRIDÆ | 33. Family VELIIDÆ |
| 31. " MESOVELIIDÆ | (MICROVELIIDÆ) |
| 32. " HYDROMETRIDÆ | 34. " GERRIDÆ |

SERIES II. CRYPTOCERATA (HYDROCORISÆ Latreille 1802) (Aquatic Forms)

- | | |
|--|--|
| 35. Family GELASTOCORIDÆ (NERTHRIDÆ, GALGULIDÆ, MONONYCHIDÆ) | 39. Family BELOSTOMATIDÆ (BELOSTOMIDÆ) |
| 36. " OCHTERIDÆ | 40. " NOTONECTIDÆ |
| 37. " NAUCORIDÆ | 41. " PLEIDÆ |
| 38. " NEPIDÆ | 42. " HELOTREPHIDÆ |
| | 43. " CORIXIDÆ |

KEY TO THE FAMILIES OF HETEROPTERA OF NORTH AMERICA

(By R. L. Usinger)

1. Antennæ shorter than head, concealed in grooves beneath the eyes and hence invisible from above except in the OCHTERIDÆ. Series CRYPTOCERATA 2
- Antennæ longer than the head and plainly visible from above. Series GYMNOCERATA 9
2. Ocelli absent 3
- Ocelli present 8

¹ Only the more important families are included, and superfamilies are omitted because of lack of uniformity in their use.

3. Base of head overlapping front margin of pronotum. Rostrum very short, scarcely distinguished from the broad apex of head. Front tarsi one-segmented, spatulate, and fringed with strong bristles. (Water Boatmen.) **CORIXIDÆ** p. 304
 Base of head inserted in pronotum. Rostrum cylindrical or cone-shaped and distinctly segmented. Front tarsi not as above. 4
4. Abdomen with a pair of short strap-like or long slender posterior appendages 5
 Abdomen without such posterior appendages. 6
5. Posterior abdominal appendages long and slender, forming a respiratory siphon. Hind legs cylindrical, formed for walking. Hind coxæ globular. (Water Scorpions.) **NEPIDÆ** p. 300
 Posterior abdominal appendages short, flat, retractile, sometimes concealed beneath the tips of hemelytra. Hind legs flattened, fringed, fitted for swimming, the hind coxæ hinged. (Giant Water Bugs.)
BELOSTOMATIDÆ p. 301
6. Body broad, oval, and flattened. Front femora tremendously enlarged and grooved along inner edge where they oppose the prehensile, curved tibiae. (Water Creepers.) **NAUCORIDÆ** p. 298
 Body strongly convex above, either elongate and large, over 5 mm., or more rounded and small, less than 3 mm. Front femora not greatly enlarged 7
7. Form elongate. Size large, 5 mm. or more. Hind tibiae and tarsi densely clothed with swimming hairs. Abdomen with a ventral trough or concavity in which is a median carinate ridge. Antennæ four-segmented. (Back Swimmers.) **NOTONECTIDÆ** p. 303
 Form suboval. Size small, less than 3 mm. Hind tibiae and tarsi scarcely, if at all, clothed with swimming hairs. Abdomen neither deeply concave nor carinate beneath **PLEIDÆ** p. 304
8. Antennæ exposed. Eyes not strongly protuberant. Front legs similar to middle pair, fitted for running. (Velvety Shore Bugs.) **UCHTERIDÆ**
 Antennæ concealed in grooves beneath the strongly protuberant eyes. Front legs raptorial, the femora very broad and grooved along their inner edges nearest the curved tibiae. (Toad Bugs.) **GELASTOCORIDÆ** p. 297
9. Claws of at least the front tarsi inserted before the apex, the tip of the last tarsal segment cleft. Superfamily GERROIDEA 10
 Claws all located at the tips of the tarsi, the tarsal apices entire. 11
10. Hind femora very long, greatly exceeding apex of abdomen. (Water Striders.) **GERRIDÆ** p. 295
 Hind femora scarcely, if at all, surpassing tip of abdomen. (Smaller Water Striders.) **VELIIDÆ** p. 295
11. Head as long as the entire thorax. (Marsh Treaders.) **HYDROMETRIDÆ** p. 295
 Head shorter, not exceeding the combined length of pronotum and scutellum 12
12. Body clothed with short, velvety pile, at least ventrally. Both clavus and membrane membranous and devoid of veins. Small (less than 4 mm.) semiaquatic bugs with legs fitted for running or walking on the water 13
 Body not clothed with fine, hydrofuge pile. Terrestrial 14

13. Rostrum four-segmented. Tarsi two-segmented. Stout little bugs with short, subequal legs. (Velvet Water Bugs.) **HEBRIDÆ**
 Rostrum three-segmented. Tarsi three-segmented, the basal segment very small. Elongate, slender bugs with long slender legs for running on the surface of the water. (Water Treaders.) **MESOVELIIDÆ** p. 295
14. Head cylindrical or narrowed and strongly extruded or produced. Front legs moderately to distinctly enlarged, raptorial. Beak often short, stout, curved, and fitted for a predacious habit 15
 Head usually broad and deeply inserted into the pronotum, and front legs usually slender. If the head is cylindrical or the front femora are enlarged and spined, then the membrane has only five simple longitudinal veins or the corium is deflected into a cuneus. 18
15. Head strongly constricted behind the eyes, the ocelli located on the posterior, subglobose lobe. Pronotum divided into three distinct lobes by transverse sutures. (Gnat Bugs.) **ENICOCEPHALIDÆ** p. 284
 Head less distinctly or not at all bilobed. Pronotum not divided into three lobes 16
16. Fourth antennal segment thickened. Front femora tremendously enlarged, subtriangular. (Ambush Bugs.) **PHYMATIDÆ** p. 284
 Fourth antennal segment not thickened, slender. Front femora scarcely to moderately incrassate 17
17. Prosternum with a longitudinal, transversely striated, stridulatory groove between the coxæ which receives the tip of the rostrum. Rostrum three-segmented. (Assassin Bugs.) **REDUVIIDÆ** p. 285
 Prosternum without a longitudinal stridulatory groove. Rostrum usually four-segmented. (Damsel Bugs.) **NABIDÆ** p. 288
18. Hemelytra with a distinct fracture subapically on the corium, producing a deflected cuneus 19
 Hemelytra without a distinct cuneus 22
19. Ocelli absent. (Leaf Bugs, Capsids.) **MIRIDÆ** p. 293
 Ocelli present 20
20. Tarsi two-segmented. Body less than $1\frac{1}{2}$ mm. long **MICROPHYSIDÆ**
 Tarsi three-segmented 21
21. Rostrum four-segmented. Apical two antennal segments without long, erect hairs. (Jumping Tree Bugs.) **ISOMETOPIDÆ**
 Rostrum three-segmented. Apical two antennal segments usually beset with long hairs or bristles. (Flower Bugs.) **ANTHOCORIDÆ** p. 292
22. Antennæ four-segmented 23
 Antennæ five-segmented 34
23. Ocelli absent 24
 Ocelli present 28
24. Hemelytra reduced to short pads without trace of membrane. Flattened species with strongly asymmetrical male genital organ. Highly modified for an ectoparasitic, blood-sucking existence 25
 Hemelytra complete or at least with some indication of membrane. Not modified as ectoparasites 26
25. Eyes absent. Ctenidia present, at least on the head and antennæ. Hemelytra consisting of nonarticulating pronotal pads. Front legs greatly enlarged. (Bat Bugs.) **POLYCTENIDÆ** p. 289

- Eyes present. Ctenidia absent. Hemelytra consisting of distinct but reduced, basally articulating wing pads. Front legs not greatly enlarged. (Bedbugs.) **CIMICIDÆ** p. 290
26. Tarsi three-segmented. Body large, robust. (Red Bugs.) **PYRRHOCORIDÆ** p. 280
- Tarsi two-segmented. Body quite strongly flattened 27
27. Hemelytra lace-like or closely reticulated. Pronotum prolonged backwards triangularly and nearly or quite covering scutellum. (Lace Bugs.) **TINGIDÆ** p. 282
- Hemelytra not finely lace-like in appearance. Pronotum not backwardly produced, the scutellum exposed. (Flat Bugs.) . . **ARADIDÆ** p. 279
28. Tarsi two-segmented, the first segment often minute 29
- Tarsi three-segmented 30
29. Rostrum four-segmented. Membrane with a few distinct veins. Upper surface covered with fine areoles. (Ash-gray Leaf Bugs.) **PIESMIDÆ** p. 282
- Rostrum three-segmented. Membrane without trace of veins. Upper surface often distinctly punctate but not areolate. (Royal Palm Bugs.) . . (THAUMASTOCORIDÆ) **THAUMASTOTHERIIDÆ**
30. Rostrum three-segmented. Hind legs enlarged for jumping . . . 31
- Rostrum four-segmented. Hind legs not as above. 32
31. First two antennal segments very stout, the apical two slender. Ocelli widely separated, nearer to eyes than to each other. Very small species, less than 2 mm. long. (Jumping Ground Bugs.)
- CRYPTOSTEMMATIDÆ**
- Antennal segments all about equally thick. Ocelli approximate, nearly contiguous. Larger than 2 mm. (Shore Bugs.) . . **SALDIDÆ** p. 294
32. Body and appendages long and slender. First antennal segment very long, bent just beyond its base. **NEIDIDÆ**
- Body and antennæ not as above 33
33. Membrane with numerous more or less distinct longitudinal veins. Antennæ often inserted high on the head, above a line drawn from middle of eyes to front end of bucculæ (including **CORIZIDÆ**, p. 278). (Squash Bugs.) **COREIDÆ** p. 277
- Membrane with only four or five longitudinal veins, the inner two sometimes joined by a cross vein. Antennæ usually inserted either on or below a line drawn from middle of eyes to front end of bucculæ. (Chinch Bugs.) **LYGÆIDÆ** p. 279
34. Scutellum very large, U-shaped, longer than the corium, covering a large part of the abdomen 35
- Scutellum smaller, triangular or moderately rounded at apex, shorter than the corium 37
35. Tibiæ with several rows of stout spines. Body small, subrounded, and shining black, often marked with yellow or red. (Negro Bugs.)
- (CORIMELÆNIDÆ) **THYREOCORIDÆ** p. 273
- Tibiæ not strongly spinose. Color and body form not as above . . 36
36. Sides of pronotum with a prominent tooth or lobe in front of the humeral angles and another at anterior angles . . . **PODOPIDÆ**
- Sides of pronotum without such protuberances. (Shield Bugs.)
- SCUTELLERIDÆ** p. 273

37. Tibiæ armed with several rows of stout spines. Front legs fossorial.
 (Ground Bugs, Burrower Bugs.) CYDNIDÆ
 Tibiæ unarmed or with only a few small or scattered spines. Front legs
 not fossorial. (Stink Bugs, Soldier Bugs.) PENTATOMIDÆ p. 275

Series I. GYMNOCERATA Fieber 1861

Section GEOCORISÆ Latreille 1825

Family CYDNIDÆ¹ (Billberg 1820) (Cyd'ni-dæ, from the Greek *κύδνος*, glorious, proud; because of the fine colors). German, Erdwanzen. Cydnid Bugs, Negro Bugs, Burrower Bugs, Ground Bugs.

A fair-sized family closely related to the PENTATOMIDÆ, in which family they were grouped until removed by Fieber in 1861. The members are small to medium-sized species. Antennæ five-segmented. Rostrum short, four-segmented. Hemelytra completely hide the abdomen. Corium subtriangular and opaque. Forelegs and also the middle legs fossorial in burrowing forms. Tibiæ spinose in sand-inhabiting species. Tarsi three-segmented and reduced in the hind legs. These insects are usually dull-colored, but a number of them are metallic and very striking. Some species, at least, burrow into the soil. The family is widely distributed throughout the world and is particularly well represented in the tropics.

The important genera are *Cydnus* Fab., *Brachypelta* Amyot and Serville, *Geotomus* Mulsant and Rey, *Gnathoconus* Fieber, *Sehirus* Amyot and Serville, *Æihus* Dallas, *Pangæus* Stål, *Amnestus* Dallas.

The members of the closely related family, THYREOCORIDÆ, including the genus, *Thyreocoris* Schrank, called negro bugs, are small shiny black or dark species which appear somewhat like small beetles. There are at least 17 species in North America. The adults frequently gather in large numbers on early spring flowers.

Species of the genus *Sehirus* are often spotted.

Family SCUTELLERIDÆ² (Leach 1815) (Scu'tel-ler'i-dæ, from the Latin *scutum*, a shield; referring to the enlarged scutellum). Scutellerid Bugs, Shield Bugs, Shield-backed Bugs.

Small to large, shield-shaped or elongated, convex bugs with enormously enlarged scutellum which may cover the abdomen and conceal the wings. They vary in color, being shiny black, brown, gray, brilliant and even metallic green, blue, red, purple, orange, and other bright hues. In size they vary from the small North American *Homæmus parvulus* (Germar), a brown species, 4 mm. long, to the Australian *Calliphara imperialis* Fab., a brilliant red species nearly

¹ Billberg 1820 used the term CYDNIDES for these bugs. The proper form as given above was by Fieber in 1861.

² SCUTELLERIDA Leach 1815; PACHYCORIDÆ Uhler 1863; SCUTELLERIDÆ Lethierry and Severin 1893, and modern authors. Until recent years these bugs have generally been grouped with the PENTATOMIDÆ, to which they are closely related.

Family PENTATOMIDÆ¹ (Leach 1815) (Pen'-ta-tom'i-dæ, from the Greek πέντε, five, + τόμος, a cut, slice; referring to the five-segmented antennæ). German, Schildwanzen. Shield Bugs, Stink Bugs, Pentatomid Bugs.

Medium-sized to large, broadly oval or shield-shaped, terrestrial, herbivorous and predacious bugs which are among the commonest and most conspicuous of insects and are familiarly known as stink bugs. Head small, triangular, with prominent median longitudinal lobe or tylus and well-developed lateral lobes or juga; prognathous or hypognathous; widest across the eyes, which distance about equals the length. Antennæ well developed, five-segmented; rarely four-segmented in exotic species. Eyes prominent; on the sides of the head near base. Ocelli two when present, rarely absent. Rostrum short or usually long, slender, straight, four-segmented, folded between coxæ. Prothorax large, almost triangular with base widest, often with distinct and curved or spine-like lateral angles and two thickenings or calli on the apical dorsal area. Transverse metapleural odoriferous gland orifices present. Wings usually well developed and frequently extending slightly beyond the tip of the abdomen. Hemelytra with clavus, corium, and membrane, but without cuneus. Membrane with many longitudinal veins arising from a vein nearly parallel with the apical margin of the corium. Legs normal in length, with very few hairs and spines. Tarsi unarmed or with small spines, two- or three-segmented. Claws and pulvilli well developed. Scutellum large but never covering the entire abdomen. Four pairs of odoriferous glands present on dorsum of abdomen in certain nymphs. These glands are atrophied in adults and replaced by the lateral thoracic glands. Female genitalia consist of a number of plates. Male genitalia with a genital plate and external genital hooks.

The members are common wherever there are plants. They are often destructive to certain cultivated crops while a number (subfamily ASOPINÆ) are predacious upon a wide variety of insects, particularly caterpillars and other larvæ. In size they vary from 5–40 mm. in length. The brown *Tessaratoma javanica* Thunberg is over 25 mm. long, has stridulating organs in both sexes, and makes a shrill noise when captured (*Trans. Ent. Soc. London*, p. 253, 1907). The giant *Oncomeris flavicornis* Burmeister of Australia, a black, maroon, orange, and purplish-blue species, is 40 mm. long. The shapes of these bugs vary considerably, and some grotesque tropical forms are known. The coloration is most remarkable. Temperate forms are often shades of gray, brown, black, or bright green, while some are combinations of bright hues. Tropical forms may be gorgeous and arrayed in the most beautiful and startling colors imaginable.

The family, one of the largest in the order, consists of some 5,000 species. It reaches its highest development in the Neotropical, Indo-Malaysian, and

¹ CORISLÆ Latr. 1804, PENTATOMIDES Leach 1815, PENTATOMIDÆ Samouelle 1819, Stephens 1829, Handlirsch 1907, and modern hemipterists; CIMICIDES Fallén 1814, Rambur 1842; CIMICIDÆ Kirkaldy 1902, 1907.

Ethiopian regions, but is truly cosmopolitan in scope. There are five or more subfamilies and many important genera. Among the latter may be mentioned the following: *Ælia* Fab., *Acanthosoma* Curtis, *Brochymena* Amyot and Serville, *Chlorochroa* Stål, *Cosmopepla* Thomas, *Euchistus* Dallas, *Eurydema* Laporte, *Eusarcoris* Hahn, *Murgantia* Stål, *Nezara* Amyot and Serville, *Pentatomia* Olivier, *Perillus* Stål, *Podisus* Herrich-Shæffer, *Sericoris* Fallén, *Strachia* Hahn, *Thyanta* Stål.

The most important North American species is probably the **harlequin cabbage bug**, *Murgantia histrionica* Hahn, a black and red species often also



FIG. 91. Eggs of the consperse stink bug, *Euchistus conspersus* Uhler. (From *Insects of Western North America*.)

marked with white, yellow, and orange, 8–11 mm. long, which is a pest of a wide variety of plants, including cabbage and other cruciferous¹ plants. Other important species in this country are: the **conchuela**, *Chlorochroa ligata* (Say); **Say's plant bug**, *C. sayi* Stål; *Euchistus impictiventris* Stål; *Cosmopepla bimaculata* (Thomas); *Thyanta custator* (Fab.); *Nezara viridula* (Linn.), also reported in Europe, Japan, India, Africa, Australia, and New Zealand; and the **green soldier bug**, *Acrosternum hilaris* (Say). Among the beneficial predacious forms may be listed the members of the genus *Brochymena* and particularly the widely distributed *B. arborea* (Say) and *B. 4-pustulata* (Fab.); the **anchorage bug**, *Stiretrus anchorago* (Fab.), the **bioculate predacious bug**, *Perillus bioculatus* (Fab.), and members of the genus *Apateticus*, especially *A. cynicus* (Say) and *A. crocatus* (Uhler).

Certain species are responsible for carrying fungous diseases of plants in tropical regions.

¹ *Bagrada picta* Fab. is a pest of cruciferous crops in India, and two species of *Eurydema* feed on similar crops in Japan.

Family **COREIDÆ**¹ Leach 1815 (Cor-e'i-dæ, from the Greek *κόρις*, *κόρεως*, a bug). Squash Bugs, Leaf-footed Bugs.

Small to large species, variable in form but more or less elongated. The colors are mostly dull shades of brown in the temperate regions and brightly varicolored in the tropics. The integument is quite hard and smooth or quite spiny. Head much narrower and shorter than the prothorax. Antennæ usually thick and frequently dilated; four-segmented; inserted at the upper parts of the sides of the head. Eyes well developed. Ocelli present. Thorax normally as wide as the abdomen. Hemelytra with corium, clavus, and membrane; the latter with numerous prominent veins; wholly membranous in the South American genus *Holhymenia* Lep. & Serv. (*Copius*). Legs variable in form; either or both the hind femora and tibiæ may have conspicuous enlargements or leaf-like dilations which give rise to the common name, "leaf-footed bugs." Abdomen large and may be concaved dorsally. Glands and stridulatory organs present. The eggs are frequently attached to the host plants, and the young may be queerly shaped and with proportionately heavier antennæ than the adults.

The members of this family are largely plant feeders, and some species are most destructive to agricultural crops. The family is a fairly large one, consisting of about 150 genera and 1,000 species. It reaches its highest development in the tropics.

The most important genera are: *Coreocoris* Hahn, *Chelinidea* Uhler, *Margus* Dallas, *Anasa* Amyot and Serville, *Alydus* Fab., *Leptoglossus* Guérin, *Jadera* Stål, *Acanthocoris* A. and S., *Narnia* Stål.

Probably the most famous member of the family is the squash bug, *Anasa tristis* (DeGeer), 16 mm. long, which ranges throughout much of North America and Central America and is often very injurious to cucurbitaceous plants, particularly pumpkins, melons, gourds, and squashes. The somewhat three-sided shiny brown eggs are deposited singly or in masses of from 15 to 40 on the stems and leaves of the hosts. Six other species of *Anasa* occur in North America.

The rice bug, *Leptocorixa varicornis* Fab. (*Leptocorisa*), is a serious pest of developing grains of rice and millet in India. It has a powerful scent and can be readily detected by the odor.

The members of the genus *Leptoglossus* Guérin usually have leaf-like enlargements on the hind tibiæ. Some are quite large with bodies up to 30 mm. long. They are plant feeders. Nine species occur in North America, of which the chinch or western leaf-footed bug, *Leptoglossus zonatus* (Dallas), *L. phyllopus* (Linn.), and *L. oppositus* (Say) are the commonest species. Members of the genera *Narnia* Stål and *Chelinidea* Uhler feed on cacti in southern United States and Mexico.

¹ COREIDES Leach 1815; COREIDÆ Samouelle 1819, Stephens 1829, Westwood 1840, Stål 1872, Reuter 1875, 1910; COREODES Burmeister 1835; COREODEA Fieber 1851; COREIDEA Costa 1860; COREIDA Stål 1865.

Family CORIZIDÆ¹ (Mayr 1866). (Cor-iz'i-dæ, from the Greek κόρις, a bug).
Corizid Bugs, Grass Bugs.

A small family of bugs formerly and still frequently grouped with the COREIDÆ, to which they are closely related. They differ in having the dorsum of

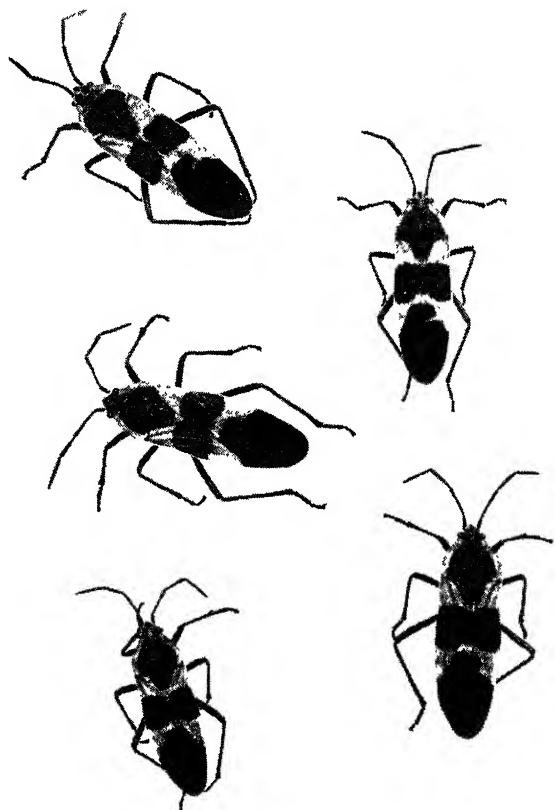


FIG. 92. The spotted milkweed bug, *Oncopeltus fasciatus* (Dallas), a medium-sized red and black lygaeid bug common to North and South America. (From *Insects of Western North America*.)

abdominal segment IV constricted medially and the gland openings of the metathorax usually obsolete or, if present, behind the posterior coxal cavities and each with two divergent grooves. The antennæ are inserted on the upper sides of the head. Ocelli are present. Membrane of the hemelytra has many longitudinal veins which may unite.

¹ Mayr 1866 used the spelling CORIZIDA. Lethierry and Severin used the proper form as given above in 1894.

The members often occur in large numbers in the open grasslands, and some species seek shelter in human habitations, where they cause considerable annoyance to the occupants. The family is widely distributed.

The important genera are *Corizus* Fallén, *Harmostes* Burmeister, *Stictopleurus* Stål, and *Rhopalus* Schilling. *Corizus hyoscyami* (Linn.), 9–10 mm. long, and *C. hyalinus* (Fab.) are the common European species while *C. hyalinus* (Fab.), *C. crassicornis* (Linn.), *C. sidae* (Fab.), *C. lateralis* (Say), and *C. bohemanii* Signoret are the most important and widely distributed species in North America. *C. hyalinus* also occurs in Central America, Africa, and Australia.

The box elder bug, *Leptocoris trivittatus* (Say), is a common and abundant bug in many parts of North America. It is black with red markings, 10–14 mm. long, and feeds and breeds upon box elder and maple trees. Adults may become very numerous and troublesome in residences under or near the host plants and may enter houses for hibernation. They also injure young fruit by their feeding punctures.

Family ARADIDÆ¹ (Spinola 1837) (Ar-ad'i-dæ, from the Greek ἀραδος, a rumbling or rattling; from the loose-armored appearance). Flat Bugs, Fungus Bugs.

Small, dull-colored, mostly gray, brown, black, broad, flat, hard bugs often with deeply sculptured exterior. Head small, angular, extended between antennæ. Antennæ short and stout; four-segmented; segment I thick, II long. Eyes well developed; somewhat hemispherical. Ocelli absent. Rostrum short; four-segmented; resting in ventral groove. Thorax wide. Hemelytra rarely completely cover the abdomen; with clavus, corium, membrane, and rarely without distinct veins; cuneus absent. Legs short; anterior coxæ inserted at middle of prosternum; tarsi usually two-, rarely three-segmented; claws without arolia. Scutellum exposed, medium-sized to large. Abdomen broader than wings; spiracles near base of segments.

The members of this family are often exceedingly thin and flat and are frequently mistaken for bedbugs. They generally live under bark and among fungi and are fungus feeders. A few attack living plants.

The family is a rather small one, comprising some 40 genera and 500 species. It is cosmopolitan in distribution but poorly represented in Africa.

The important genera are *Aradus* Fab. and *Aneurys* Curtis which are well represented in North America and less so in Europe; and *Mezira* Amyot and Serville with seven species in North America.

Family LYGÆIDÆ² (Schiller 1829) (Ly-gæ'i-dæ, from the Greek λυγαῖος, shadowy, gloomy; in reference to some of the small, somber-colored forms).

Chinch Bugs, Lygæid Bugs.

Small to medium-sized, oval and elongated, somber and brightly colored bugs living on the ground and on plants. Head short. Antennæ four-segmented,

¹ These bugs were first associated with the bedbugs, CIMICIDÆ. Spinola designated them as ARIDIDES in 1837 and Costa as ARADIDÆ in 1852.

² The members of this family were early grouped with the COREIDÆ. They were also

inserted well down on the face, apical segment often enlarged; some have a malformation known as oligomery. Eyes normal to large and exserted. Ocelli usually present. Rostrum four-segmented. Legs short; forelegs normal or raptorial in the subfamily APHANINÆ; tarsi three-segmented. Hemelytra with elongated clavus and membrane prominent and with a few irregular longitudinal veins. Micropterism, or the tendency to have small wings, is not uncommon in this family. Abdominal segment VII of the male enlarged.

This is a large family of some 2,000 species and cosmopolitan in distribution. The members are mostly phytophagous, but a few are thought to be predacious. Certain members of the subfamily BLISSINÆ are quite destructive to various cereal crops, and some *Oxycarenus* are important pests of cotton. The family is divisible into some 12 subfamilies and more than 100 genera.

The most important genera are: *Blissus* Burmeister, *Nysius* Dallas, *Ischnodemus* Fieber, *Lygæus* Fab., *Oncopeltus* Stål, *Cymus* Hahn, *Geocoris* Fallén, and *Oxycarenus* Fieber. The most important species is the chinch bug, *Blissus leucopterus* (Say), a small dark bug 3-4 mm. long which is a serious pest of cereals in much of North America. *B. gibbus* Fab. is common on grasses and sugar cane in India but is not harmful. The false chinch bugs of the genus *Nysius* are widely distributed and very general feeders. *N. thymi* Wolff and *N. ericæ* (Schilling) of Europe and North America, *N. minutus* Uhler of North America, and *N. vinitor* Bergroth of Australia are the important species.

Many species, such as the beautiful European *Lygæus equestris* Linn., the North American *L. reclinatus* Say, and *Oncopeltus fasciatus* (Dallas), feed on milkweeds (*Asclepias*). These two genera are widespread.

The big-eyed bugs of the genus *Geocoris* are quite abundant in many parts of the world and are considered beneficial because of their predacious habits in destroying insects. The genus is represented by nine species in North America. *G. bullatus* (Say), *G. pallens* Stål, *G. punctipes* (Say), and *G. uliginosus* (Say) occur throughout much of the continent. Lefroy (1909) records *G. tricolor* Fab. as predacious on the palm mealybug, *Pseudococcus nipæ* (Maskell), on cotton in India.

Family PYRRHOCORIDÆ¹ Fieber 1861 (Pyr'rho-cor'i-dæ, from the Greek πυρρός, red, tawny, reddish, flame-colored, + κόρις, a bug; referring to the brilliant red colors of some species). German, Feuerwanzen. Red Bugs, Fire Bugs, Cotton Stainers, Bordered Plant Bugs.

Medium-sized to large, regularly rounded, elongated or stout, dull or brightly colored herbivorous bugs, varying in length from 5-50 mm. Head rather small. Antennæ well developed, thick, four-segmented. Eyes large. Ocelli absent. Rostrum long, four-segmented. Prothorax large, hind margin often slightly wider than mesothorax. Wings well developed or brachypterous and usually

designated as LYGÆIDES Schiller 1829; LYGÆODES Burmeister 1835; LYGÆIDÆ Herrich-Schæffer 1835, Westwood 1840, Dallas 1852, Baer 1860, Stål 1860, Reuter 1875, Handlirsch 1909, and modern writers; MYODOCHIDÆ Kirkaldy 1899, Reuter 1910; GEOCORIDÆ Kirkaldy 1902, 1907.

¹ These bugs were early associated with both of the families COREIDÆ and LYGÆIDÆ.

extending beyond tip of abdomen. Hemelytra with corium, clavus, and with normal, short, or greatly reduced membrane; membrane with two large basal cells which emit four large and three or four other branching veins. Legs normal, rounded. Tarsi three-segmented with claws and arolia.

The brilliant red colorations of some species have been referred to as warning colors. The members have habits similar to those of the COREIDÆ and LYGÆIDÆ, many species being highly destructive to cotton and other agricultural crops. The family is a small one, consisting of some 50 genera and

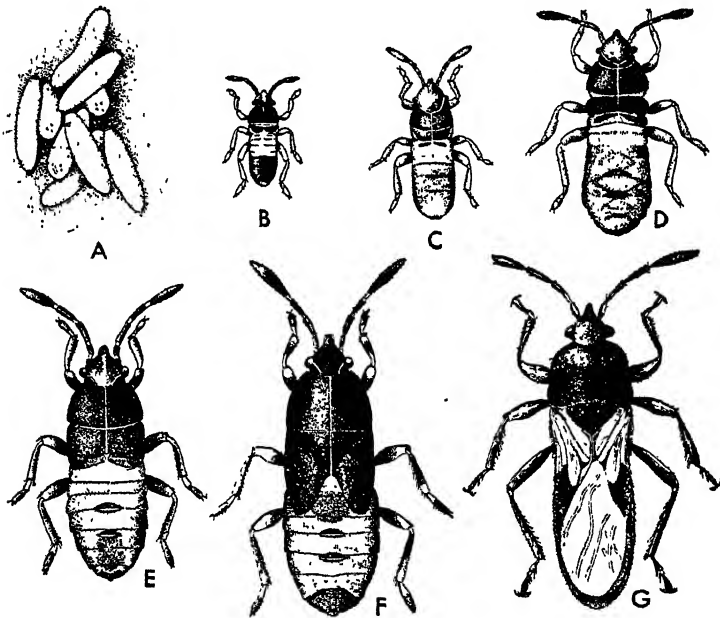


FIG. 93. The life history of the chinch bug, *Blissus leucopterus* (Say), showing the instars from egg to adult. (After Luginbill, U.S.D.A., 1922.)

450 species distributed throughout the world. The most important genera are *Antiloclus* Stål, *Dysdercus* Amyot and Serville, *Dindymus* Stål, *Ectatops* A. and S., *Euryophthalmus* Laporte, *Physopelta* A. and S., and *Pyrrhocoris* Fallén.

The genus *Dysdercus* contains the most important injurious species which are more or less specific on cotton and other malvaceous plants. There are at least 20 species attacking cotton in various parts of the world. *D. cingulatus* (Fab.) is the red cotton bug of oriental and eastern Asia; *D. albidiventris* Stål and *D. suturellus* (H. S.) are the cotton stainers of southern United States and range southwards into South America; *D. ruficollis* (Linn.) in Brazil and Peru; *D. andreae* (Linn.), *D. delauneyi* Lethierry, *D. howardi* Ballou, and four other species occur on cotton in the West Indies; *D. sidae* Montrouzier is the red

cotton bug of Australia; and *D. nigrofasciatus* Stål and seven other species occur on cotton in Africa.

The genus *Euryophthalmus* contains seven North American species. The bordered plant bugs, *E. cinctus* (H. S.) and *E. succinctus* (Linn.), are the most important. *Pyrrhocoris* has two common European species: *P. apterus* Linn. and *P. ægyptius* Linn. The former is brachypterous and occurs in Europe, Africa, Asia. *Dindymus versicolor* H. S. is listed as a pest of fruits in Australia and New Zealand by Tillyard (1926). The Sumatran species, *Lohita grandis* Gray, a large, conspicuous red and black bug, measures over 50 mm. in length. It also feeds on cotton in India (Sharp, 1899).

Family TINGIDÆ¹ (Laporte 1832) (Ting'i-dæ, from Tingi, ancient name of Tangiers, a village in Morocco²). German, Gitterwanzen. French, Tingidides. Lace Bugs, Tingids.

Minute to small bizarre bugs, scarcely more than 4–5 mm. long, with the dorsum of the head, prothorax, and hemelytra reticulated in frame-like raised and sunken pattern somewhat resembling lace.³ Bodies small, thin, flattened, and frequently spiny in the immature forms and often covered by a much wider dorsal armature in the adult stage. Head much narrower than or as wide as the prothorax. Antennæ short, four-segmented, segment III longest, segment IV frequently clavate or capitate. Eyes well developed. Ocelli absent. Rostrum short, four-segmented. Pronotum sometimes greatly modified to form a raised hood concealing the head and with disk-like lateral lobes (paranota) extending far beyond the margins of the prothorax. Wings fully or partially developed even within the species. Hemelytra transparent or pigmented, just covering the abdomen or greatly expanded and extending far beyond the margins of the body, variously raised in ridges and depressions or nearly flat; the surface divided by veins into costal, subcostal, and discoidal areas and many areoles. The margins of the paranota and hemelytra may be fringed with spines. Legs normal. Fore coxæ near base of prosternum. Tarsi two-segmented. Claws without arolia.

These remarkable insects are thought to be wholly plant feeders, and some species greatly injure wild and cultivated plants. The eggs are frequently

¹ The proper spelling of the family name of these insects has long been the subject of much debate and controversy. The difficulty has arisen from the transliteration of the Greek root from which the generic name *Tingis* was erected by Fabricius in 1803. Some of the opinions are: TINGIDITES Laporte 1832, Spinola 1837; TINGIDÆ Westwood 1840, Lethierry and Severin 1896, Kirkaldy 1908, Osborn and Drake 1917, Drake 1919, Parshley 1923, Butler 1923, Tillyard 1926, Imms 1930, Hedicke 1935, Perrier 1935; TINGIDITÆ Spinola 1850; TINGIDIDÆ Fieber 1860, Distant 1903, Oshanin 1908, Schröder 1925, Weber 1930, Brues and Melander 1932; TINGITIDÆ Stål 1873, Uhler 1886, Champion 1897, Horvath 1906, Osborn and Drake 1916, Holland 1924, Horvath and Parshley 1927. The matter has been fully discussed by W. J. Holland (*Ann. Ent. Soc. Am.* 17: 95–96, 1924).

² Perrier, Remy, *La Faune de la France* 4: 39, 1935.

³ Members of the closely related family PIESMIDÆ Amyot and Serville 1843 have a similar reticulated surface structure but have ocelli, larger wing cells or areoles, and exposed scutellum. The ARADIDÆ are also similar, but the reticulations neither are so lace-like nor hide the body so completely.

inserted into the tissues of the hosts, and the young are often dark, spiny individuals appearing quite different from the adults. All forms usually feed upon the undersides of the leaves where their cast skins and small dark specks of excrement remain as evidences of their presence. Some species, including *Copium cornutum* Thunberg and *C. teucriti* Host, produce leaf galls on *Teucrium* in Europe. Other species frequent moss.

The family is a medium-sized one with 150 genera and about 700 species. It is especially well represented in the Holarctic region or the Northern Hemi-

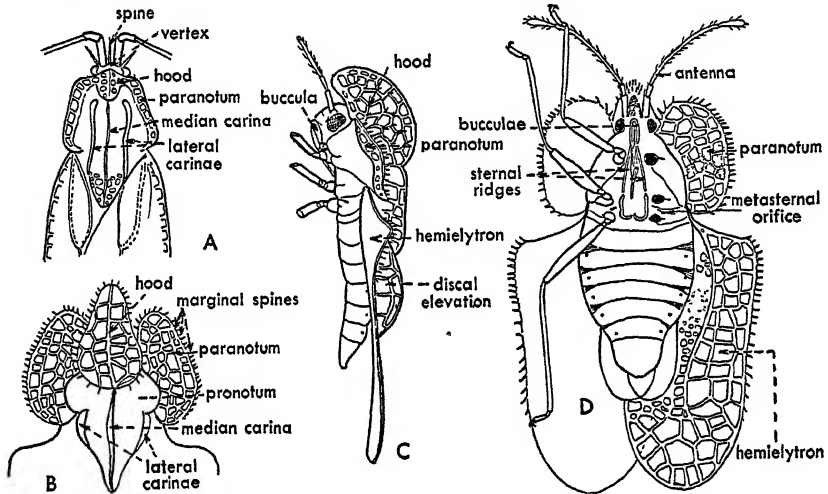


FIG. 94. TINGIDÆ or lace bugs. A, *Leptostyla oblonga* (Say), dorsal aspect of head and thorax; B, *Corythucha ciliata* (Say), dorsal view of thorax; C, lateral and D, ventral aspects of same. (Drawing by Garman, *Hemiptera of Connecticut*, 1923.)

sphere and appears more specialized in the Old World than in the New. Important genera are *Acalypta* Westw., *Corythucha* Stål, *Dictyonota* Curtis, *Galeatus* Curtis, *Gargaphia* Stål, *Leptostyla* Stål, *Monanthia* Lep. and Serv., *Serenthia* Spinola, and *Tingis* Fab.

The sycamore lace bug, *Corythucha ciliata* (Say), is a serious pest of sycamores throughout North America, and *C. incurvata* is a pest of the ornamental California Christmasberry in California and Arizona. *Froggattia olivina* Horvath is injurious to olives in Australia. *Gargaphia solani* Heidemann feeds on various solanums including eggplant and on cotton, and often seriously injures the latter in North America. *Leptobyrsa rhododendri* (Horvath) is an important pest of rhododendrons in Europe and in North America and also feeds on *Kalmia* and other plants. *Stephanitis azaleæ* Horvath and *S. pyrioides* Scott attack azaleas in Japan. *S. pyri* Fab. is injurious to apples and pears in Europe while *S. ambigua* Horvath infests cherries and pears in Japan. The Mexican *Teleonemia lantanæ* Distant is claimed to have proved effective in the biological control of the lantana in Hawaii.

Family ENICOCEPHALIDÆ ¹ Stål 1860 (En'i-co-ceph-al'i-dæ, from the Greek ἐνικός, singular, unique, + κεφαλή, head; referring to the peculiar slender and lobed head). Unique-headed Bugs, Gnat Bugs, Clear-winged Bugs.

Small to medium-sized predacious bugs similar to the assassin bugs. Head two-lobed, emarginated behind the eyes, and with the enlarged posterior lobe subglobose. Antennæ four-segmented. Eyes large. Ocelli distinct, situated on posterior lobe. Rostrum primitive, robust or slender, four-segmented. Prothorax usually divided into three distinct lobes; stridulatory organs absent on prosternum. Legs round or flat. Forelegs more or less raptorial; tibiae dilated apically; tarsi one-segmented. Tarsi of middle and hind legs three-segmented. Claws long and spine-like. Arolia absent. Hemelytra wholly membranous² with few longitudinal and cross veins; large cells in hemelytra.

A small family of some 70 species widely distributed in many parts of the world. The members are hunters that feed upon small mites and insects. They are to be found chiefly in debris on damp ground, under bark, free upon plants, and a few in ants' nests. Some species emit a musty odor, and the adults of several genera have been observed to gather in swarms in the evenings in what are thought to be dancing nuptial flights like those of gnats, flies, and mayflies.

The important genera are *Enicocephalus* Westwood (*Henicocephalus*), *Systelloderes* Blanchard, *Cocles* Bergroth, and *Ærorchestes* Bergroth. *Enicocephalus formicina* (Uhler) occurs in California; *Systelloderes biceps* (Say) in various parts of North America, and *S. iowensis* Drake and Harris in Iowa. The last has been recorded as preying upon the adults of the Hessian fly.

Family PHYMATIDÆ ³ (Laporte 1833) (Phy-mat'i-dæ, from the Greek φῦμα, a growth, tumor, swelling; referring to the robust form or swollen abdomen of the males). Ambush Bugs.

Medium-sized, rather robust, odd-shaped, sculptured and spiny, slow-moving, predacious bugs that inhabit flowers and foliage and lie in wait for other insects which they grasp with their strong forelegs and eat alive. Head small, set into thorax. Antennæ rather short, four-segmented, apical segment enlarged, may be hidden in grooves along the sides of head and pronotum. Eyes well developed; on sides of head. Ocelli present. Rostrum short, four-segmented, the first segment rudimentary. Thorax often thick and with sharp angles and spines. Wings, when folded, often much narrower than the abdomen. Hemelytra with well-defined corium, clavus, and membrane; the

¹ This family has generally been united with the REDUVIIDÆ, to which it is closely related. It is often spelled HENICOCEPHALIDÆ. The type genus, *Enicocephalus*, was established by Westwood in 1837 (*Trans. Ent. Soc. London* 11: 22-23, 1837) and the family name has followed this spelling.

² The hemelytra of the family HEBRIDÆ and the South American genus *Holhymenia* (COREIDÆ) are also practically membranous.

³ PHYMATITES Laporte 1833; PHYMATINI Costa 1838; PHYMATITE Spinola 1850; PHYMATIDÆ Costa 1852, Dohrn 1859, Lethierry and Severin 1896, Handlirsch 1907, Horvath 1911, and modern authors; MACROCEPHALIDÆ Dohrn 1866, Stål 1866; SPINIPEDES Walker 1872.

corium veined and the membrane with two to four cells and many veins. Forelegs short, stout, raptorial; femora thick; tibiae and tarsi modified to grasp and hold prey, even rarely pincer-like; tarsi two-segmented, small or absent. Middle and hind legs normal; tarsi two-segmented. Abdomen of male modified, segment VI enlarged; VII hidden by VIII which forms a genital plate.

A small family of bugs which feed upon many kinds of insects and destroy honeybees and other beneficial insects as well as destructive ones. There are about 150 species, living mostly in tropical America and Asia, with some Palearctic and Nearctic forms. There are but two important genera: *Phymata* Latr. and *Macrocephalus* Swederus. *Phymata* is represented in southern Europe by two species, *P. crassipes* Fab., 8 mm. long, and *P. monstrosa* Fab., 6 mm. long. In North America Van Duzee (1917) lists 14 species. *P. erosa* (Linn.) is most widely distributed and has a number of varietal forms occurring in various parts of the country. *Macrocephalus* has also six North American species widely distributed, apparently Neotropical in origin.

Family RUDUVIIDÆ¹ (Latreille 1807) (Red'u-vi'i-dæ, from the Latin *reduvia*, a hangnail, a remnant, fragment). German, Raubwanzen. Assassin Bugs, Kissing Bugs,² Reduviid Bugs.

Small to large, robust or elongated, somewhat flattened, smooth, hairy or spiny, active or sluggish, predacious bugs, which commonly occur on the ground, in flowers, and on various types of plants where they await or hunt living prey. Head narrow, longer than broad, pointed anteriorly, often with neck, free. Antennae filiform, apical segments often very fine and frequently broken off; four- or five-segmented. Eyes well developed; near middle or at base of head. Two ocelli present or absent; situated behind the eyes. Rostrum short, curved, three-segmented or rarely with an extra basal segment; pointed, and with the tip resting in a furrow between the fore coxae. This furrow or sulcus is regularly transversely striated, and, together with the rostrum, which moves at right angles across them, the striae form a stridulating mechanism. Prothorax prominent, smooth, ridged, spined, or sharply angular; pronotum often with transverse depression dividing it into two lobes. Wings well developed, abbreviated, or absent. Hemelytra with corium and clavus, without cuneus; membrane well developed with two or three large basal cells or areoles. Legs normal, hairy or spiny. Forelegs somewhat raptorial. Tarsi one-, two-, or three-segmented, with claws and without arolia. Thoracic ventral glands absent. Abdomen often wide and concave along the dorsum so that the wings, which are often narrower than the body, fit closely into the furrow.

This large family exhibits a remarkable variety in form, coloration, and habits. The color varies from black, brown, and gray in combination with

¹ Latreille established this family under the name REDUVINI in 1807. The proper form REDUVIIDÆ was first formed by Stephens in 1829.

² The name "kissing bug" arises from newspaper accounts in 1899 concerning one of these bugs which pierced the lip of a lady.

bright hues of yellow, orange, and red. The biologies of many species are known. In addition to the normal predacious types which feed upon insects in general and are more or less beneficial, there are those which invade habitations in search of bedbugs and other household pests and which often inflict severe wounds on humans. *Triatoma sanguisuga* (Lec.), of North America and *T. rubro-*

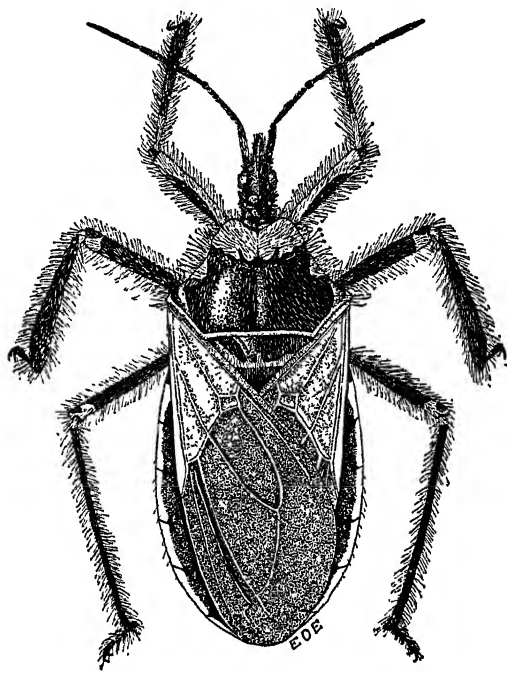


FIG. 95. The bee assassin, *Apiomerus crassipes* (Fab.), a predacious bug that captures bees and other insects chiefly in flowers. (From *Insects of Western North America*.)

fasciata De Geer, a nearly cosmopolitan species, belong to this class. Others, which suck blood from rodents and other lower animals and man, are carriers of trypanosomes that cause serious complications and even death to man. *Triatoma megista* (Burm.), *T. infestans* Klug, *T. rubrovaria* Blanchard, and other species transmit Chagas' disease caused by the trypanosome, *Trypanosoma cruzi* Chagas, in South America. *Triatoma uhleri* Nieva transmits *Trypanosoma triatomæ* Kofoid and McCulloch among wood rats in California. *Triatoma rubrofasciata* (De Geer) is suspected as an agent in the transmission of kala azar or black sickness in India.

A number of species live under rocks and among debris. The sticky immature forms are camouflaged under a mass of particles that completely hide them, as is the case of the masked bedbug hunter, *Reduvius personatus*

(Linn.), a dark-brown and black species, 15–20 mm. long, that is widely distributed throughout the Northern Hemisphere and Australia.

The bee assassins, *Apiomerus crassipes* (Fab.) of North America and *Prisihesaucus papuensis* Stål of Papua and northern Australia, feed upon bees which they capture in flowers.

The eggs are often laid singly or in compact clusters on the various plants and objects. Some of them are curiously ornamented at the micropylar or apical end.

The family is represented by a number of subfamilies, some 300 genera, and about 2,500 species. It reaches its highest development in the tropical and warmer temperate regions. The most important genera of the north temperate region are *Apiomerus* Laporte, *Arilus* Burmeister, *Melanolestes* Stål, *Rasahus* Amyot and Serville, *Reduvius* Linn., *Sinea* A. and S., *Triatoma* Laporte, and *Zelus* Fab.

Other interesting species not mentioned above are the giant wheel bug, *Arilus cristatus* (Linn.), a brown species 25–30 mm. long which gets its name from a half-circular crest resembling a cogwheel. It preys upon caterpillars and other soft-bodied insects. The corsairs, *Rasahus biguttatus* (Say) and *R. thoracicus* Stål, are amber and black species with a pale spot in each wing membrane. They are nocturnal, stridulate when captured, and inflict a painful bite if given the opportunity.

An antidote for the painful bites of these bugs consists in a generous compress of epsom salts applied immediately to the wound, which is then kept thoroughly soaked for some hours.

Family PLOIARIIDÆ ¹ Dohrn 1863 (Plo'i-ar-i'i-dæ, from the Greek πλοῖαριον, a small boat). Thread-legged Bugs.

A small family of remarkably slender, delicate bugs with long bodies and thread-like appendages. Head cylindrical, long. Eyes prominent. Ocelli absent. Antennæ long and slender, sometimes geniculate, and enlarged apically. Rostrum three-segmented, segment I stout and curved. Forelegs raptorial; coxæ greatly elongated. Middle and hind legs long and filamentous. Tarsi three-segmented. Prosternum long and narrow with a median cross-striated stridulatory groove between the fore coxæ in which the tip of the rostrum rests.

These small to long fragile bugs are very deliberate and slow moving, yet they can act very quickly with their forelegs in seizing the living prey upon which they feed. They are often captured in sweeping vegetation and in beating shrubs and trees, but very little is known about their biology. Because of their similarity in structure and habits they have generally been associated with the assassin bugs of the family REDUVIIDÆ. The family is widely distributed. The most important genera are *Ploiaria* Latr., *Emesa* Fab., *Emesopsis*

¹ This family was for years known as the EMESIDÆ Walker 1873 from the supposed first genus *Emesa* Fab. 1803. However, the genus *Ploiaria* was erected by Latreille in 1802 and it became the type genus of the family PLOIARIIDÆ Dohrn 1863.

Uhler, *Empicoris* Wolff, *Gardena* Dohrn, *Ghilianella* Spinola, *Barce* Stål, and *Stenolemus* Signoret.

Ploiaria culiciformis DeGeer is a common species in Europe and extends into western Asia and northern Africa. Four species occur in North America, of which *P. errabunda* (Say) is the best known.

Ploiaria brevipennis (Say) is a very common species throughout much of North America and *Barce annulipes* Stål and *B. fraterna* (Say) are widely distributed east of the Rocky Mountains. *Ploiaria huttoni* (Scott) is a wingless species in New Zealand and in Juan Fernandez Island off the central coast of Chile.

Empicoris rubromaculatus (Blackburn) is our commonest species, occurring in North and South America and in Hawaii.

Family NABIDÆ¹ (Costa 1852) (Nab'i-dæ, from the Latin *nabis*, a giraffe; referring to the elongated prothorax and head or the long rostrum).
Damsel Bugs.

Medium-sized, slender, predacious bugs; gray, brown, black, or reddish in color; dull, shining, pubescent or hairy. Head elongate. Antennæ long, slender, normally four-segmented; five-segmented in certain exotic forms; a supplementary ring segment may be present at base of II. Eyes well developed. Ocelli present, normal or reduced. Rostrum long, four-segmented, rarely three-segmented. Prothorax long and narrow; pronotum with anterior impression and prosternum without stridulatory groove. Wings normal or greatly reduced, some forms dimorphic. Hemelytra with corium, large clavus, membrane, and sometimes an embolium; cuneus absent; membrane with two or three large elongated cells and radiating veins with few connecting cross veins. Legs slender; fore pair raptorial. Tarsi three-segmented. Claws without arolia. Abdomen slender or wide. Female with ovipositor. Male with abdominal segment IX enlarged and with copulatory hooks.

The members of this family are largely predacious on plant bugs and other smaller insects and are therefore considered beneficial. They occur generally upon vegetation.

The family is closely related to the REDUVIDÆ, with which it was formerly combined. It is widely distributed and consists of about 350 species. The important genera are *Arbela* Stål, *Nabis* Latr., and *Pagasa* Stål. The genus *Nabis* is most widely distributed and is practically cosmopolitan. There are eight common species in Europe, 50 in North America, one in Australia, and two in New Zealand. *Nabis fesus* Linn. is the commonest species and one of the best known members of the order. It is a dull-gray bug, 8 mm. long, which occurs throughout the Northern Hemisphere. The brachypterous *N. apterus* Fab. is Palearctic and does not occur in North America.

¹ The correct spelling NABIDÆ was first used by Dohrn 1859. Hedicke 1935 spells the name NABIDIDÆ.

Family POLYCTENIDÆ (Westwood 1837) (Pol'y-cten'i-dæ, from the Greek πολύς, many, + κτέλς, κτερός, comb; referring to the many combs or ctenidia¹ on the body). Bat Bugs, PolycTENids, Many-combed Bugs.

A small family of very peculiar bugs which are viviparous and ectoparasitic on bats. They are small, elongate, flattened insects closely allied to the CIMICIDÆ. The color is brownish, and the bodies are beset with hairs and setæ. A

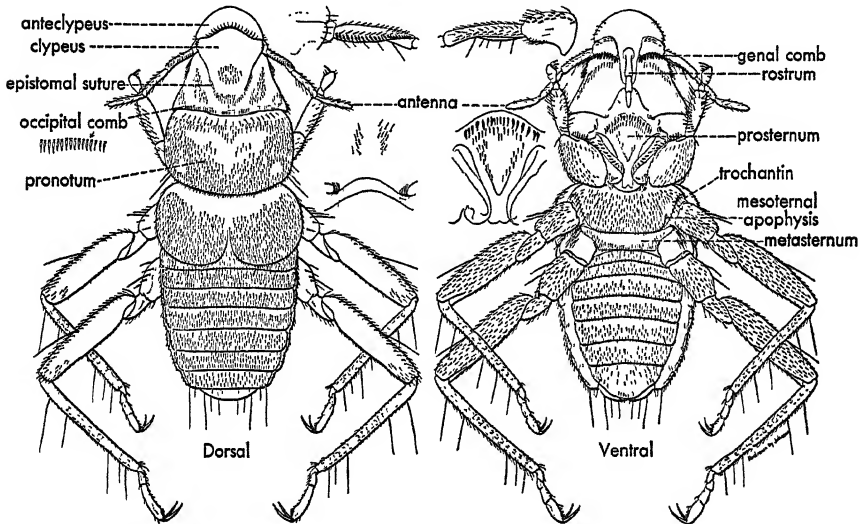


FIG. 96. The bat bug, *Hesperoctenes impressus* Horvath, a South American ectoparasite of free-tailed bats. (Redrawn from Ferris, 1939.)

very important characteristic is the presence of ctenidia, which may occur on antennal segments I and II, the genæ, posterior margins of the head and pronotum, apices of the mesonotal lobes, the prosternum, the venter of abdominal segment I, and the terminal tarsal segment. These groups of comb-like spines may not all be present on certain species. Head widely triangular or rounded in front. Antennæ four-segmented. Eyes absent. Rostrum four-segmented (apparently three-segmented in *Ctenoplax*). Labrum well developed, flap-like. Thorax well developed and almost as long as the abdomen. Hemelytra reduced to mesonotal lobes such as occur in the nymphs of most HEMIPTERA; true wings absent. Legs well developed; femora incrassate; forelegs short, middle and hind legs long, tarsi three-segmented and with an extra false segment. Claws similar or asymmetrical, with or without a basal tooth. Arolia absent.

¹ Ctenidia in this restricted sense also occur on the beaver parasite, *Platypsyllus castoris* Reitsema, in the order COLEOPTERA; on the bat parasites belonging to the family NYCTERIBIIDÆ in the order DIPTERA; and on many of the fleas in the order SIPHONAPTERA.

The members of this family comprise six genera and 18 species and have recently been reviewed by Ferris and Usinger (1939). Members occur on all the continental areas in the tropical and subtropical regions. The present distribution includes five species from Africa, five from the East Indies, one from China, one from India, three from North America, seven from South America, two from Central America, and one from the West Indies. They have been taken thus far on only four families of bats: MOLOSSIDÆ or free-tailed bats; NYCTERIDÆ or false-vampire bats; PHYLLOSTOMIDÆ or leaf-nosed bats; and PTEROPIDÆ or fruit-eating bats. By far the greater number of polyctenids occur on the first-mentioned family.

Polycenes molossus Giglioli 1864 was the first species described and is the only member of that genus. It occurs in India.

The North American species are: *Hesperoctenes eumops* Ferris and Usinger from the bat, *Eumops californicus*, in California; and *Hesperoctenes hermsi* Ferris and Usinger from the free-tailed bat, *Tadarida macrotis*, in Texas. Only 74 specimens have been taken in the entire world thus far.

Family CIMICIDÆ¹ (Latreille 1804) (Ci-mic'i-dæ, from the Latin *cimex*, *cimicis*, a bug). German, Bettwanzen. French Cimicidés, Punaises des lits. Bedbugs, Flats, Swallow Bugs.

As now defined this is a very small family of temporary ectoparasites or predators which feed upon warm-blooded animals including man, birds, and bats. They are for the most part small, oval, thin and flat, somber reddish-brown bugs with tough integument and naked or pubescent bodies. Head short, broad, and set into the prothorax. Antennæ four-segmented. Eyes well developed. Ocelli absent. Clypeus distinct. Rostrum short, three-segmented; resting in a ventral groove. Pronotum characteristically notched anteriorly to receive the head and ventrally grooved for the rostrum. True wings are absent, and the hemelytra are represented only by mere stubs. The legs are short; the tarsi three-segmented. The abdomen may be asymmetrical; metapleural glands present.

There is still some confusion as to the exact number of species, arising from the early belief that each was confined to a single host. It is now known that nearly all species may feed upon different hosts. Yet the host range is not great since all the known species are limited to three groups of animals as indicated above. The 36 species are grouped chiefly into the genera *Cimex* Linn., *Æciacus* Stål, *Cacodmus* Stål, and *Hæmatosiphon* Champion. They are mostly of Old World origin, and those attacking man and domesticated fowls have been carried to nearly all parts of the inhabited world.

¹ CIMICIDES Latreille 1804, 1807; CIMICIDA Leach 1815; CIMICIDÆ Samouelle (included *Reduvius* Fab. *Ploiaria* Scopoli, *Cimex* Linn., and *Tingis* Fab.), Stephens 1829, Westwood 1840, and recent authors; ACANTHIIDÆ, ACANTHINI Costa 1852; ACANTHIIDÆ Dohrn 1859; ACANTHIIDA Stål 1865; CLINOCORIDÆ Kirkaldy 1806, 1909; CACODMIDÆ Kirkaldy 1899.

The families DIPSOCORIDÆ (CERATOCOMBIDÆ) and ANTHOCORIDÆ are combined with this family by many authors.

Two species attack humans: the bedbug, *Cimex lectularius* Linn., and *C. rotundatus* Signoret. The former is a temperate and subtropical species which has the posterior margin of the prothorax straight, and broad lamellate pronotal margins. The latter, which is chiefly confined to tropical Africa and Asia, has the posterior margin of the pronotum rounded, and very narrow, flattened pronotal margins. The bugs are nocturnal in habit and during the day secrete themselves in cracks of the dwelling or furniture, under carpets,



FIG. 97. The bedbug, *Cimex lectularius* Linn., sucking blood from the human hand. (Photo by Doten from *Insects of Western North America*.)

and in debris. Their thin bodies are well adapted to such a life. The female of *C. lectularius* lays from 50 to 200 cylindrical, yellowish-white eggs with a raised rim at one end containing the micropyle. The surface of the egg is punctured and the length about 1 mm. The newly hatched young are pale with red eyes and a darker band across the abdomen. Maturity is reached in the fifth instar, the length being 4–5 mm. and the color fuscous. The full life history requires about 7 weeks under favorable conditions and 6 months during the winter or in cold regions. It is found associated only with humans and has often been referred to as a domesticated insect. It has been intimately associated with man throughout the ages.

A peculiarity of these bugs is the Berlese organ and the organ of Ribaga. The former, also referred to as the "spermatophagous organ," is located in abdominal segments IV or V. It consists of a bursa associated with the spermatheca whose cells store and are thought to ingest and destroy the excess spermatozoa. The organ of Ribaga is a sperm sac connected with the former and communicates with the exterior by means of a conspicuous notch in abdominal segment IV (Butler 1923, Wigglesworth 1939).

Cimex columbarius Jenyns infests pigeons and occurs in pigeon cots in various parts of Europe. *C. pilosellus* (Horvath) feeds on bats in North America.

The swallow bug, *Ecicacus hirundinis* Jenyns, is common on swallows and martins in Europe, and *O. vicarius* (Horvath) acts a similar rôle in North

America. They remain in the old deserted nests until the birds return to occupy them the following year. These bugs are clothed with fine, silky hairs.

The poultry bug, *Hematosiphon inodorus* (Dugés), is a serious pest of poultry in Mexico, Texas, and New Mexico. It is reported as invading human habitations and being most annoying to man.

Family ANTHOCORIDÆ¹ (Amyot and Serville 1843) (An'tho-cor'i-dæ, from the Greek *ἄνθος*, a flower, + *κόρις*, a bug; flower bugs). Flower Bugs, Minute Pirate Bugs.

Minute to small bugs. Head prolonged beyond insertion of antennæ. Eyes large and near prothorax. Antennæ four-segmented; segments III + IV less than twice the length of I + II. Ocelli present or absent, sometimes present in male and absent in female of same species. Rostrum long, free, three- to four-segmented. Hemelytra with distinct cuneus and large embolium; corium abbreviated, indistinct, or absent. Legs normal; tarsi two- or three-segmented.

These are free-living bugs which occur in debris on the ground and on plants and are often abundant in flowers and in pseudogalls caused by aphids upon which they feed. Other hosts are plant mites, thrips, leafhoppers, psyllids, scale insects, phylloxerids, adelgids, whiteflies, and similar small insects. They are considered beneficial.

The members of the family are widely distributed from the subarctic into the tropics but reach their highest development in the Palæarctic region. About 65 genera and 400 species are known. The most important genera are *Anthocoris* Fallén, *Lyctocoris* Hahn, *Orius* Wolff (*Triphleps* Fieber), and *Xylocoris* Dufour.

The field anthocorid, *Lyctocoris campestris* Fab. [*L. domesticus* (Schilling)], 3.5 mm. long, is a cosmopolitan species abundant in Europe and possibly distributed by commerce. It is now common in Europe, Africa, Asia Minor, North America, Australia, and New Zealand, occurs in human habitations, and has been known to bite humans. It also lives on plants and in the thatch of straw stacks, in granaries, flour mills, pigeon cots, swallows' nests, bumblebees' nests, and among fungi (Butler 1923) where it feeds upon a wide variety of insects and other forms of animal life. *Anthocoris kingi* Brumpt also sucks human blood. *A. nemorum* Linn. is one of the commonest species in Europe and western and northern Asia. The adults are 3 mm. long. The species is predacious upon larvæ of MICROLEPIDOPTERA, on aphids and other small insects, and is also reported as attacking plants, including hops (Butler 1923). *A. nemoralis* Fab., likewise of Europe, has similar habits and is also frequently noted as attacking gall aphids, particularly on elm and poplar.

Orius niger (Wolff), 2.5 mm. long, *O. majuscula* Reuter, and *O. minuta* Linn. of Europe are common on many plants and prey upon aphids, thrips, and other small insects. The first species also occurs in North America as also does *O. insidiosus* (Say) (*O. tristicolor* White). They are all predacious on mites,

¹ These bugs were designated as ANTHOCORIDES by Amyot and Serville 1843 and as the proper form ANTHOCORIDÆ by Dallas in 1852.

thrips, aphids, and leafhoppers, on eggs and newly hatched caterpillars of the corn earworm and other moths, and on other small animals, and are at times of some importance in reducing the numbers of these pests. *O. sauteri* (Poppius) feeds upon the mulberry leafhopper in Japan.

Family MIRIDÆ¹ Hahn 1831 (Mir'i-dæ, from the Latin *mirus*, wonderful).

German, Weichwanzen. Plant Bugs, Leaf Bugs, Capsids, Mirids.

Small to medium-sized, ovate, oblong, or slender, somewhat flattened, fragile, active species with soft integument, smooth, shiny, pubescent or hairy bodies, and black, dull, or brilliant colors. Head small, often sharply produced. Antennæ well developed, four-segmented, slender. Eyes well developed. Ocelli absent. Rostrum long, four-segmented; first segment as long as or longer than head. Prothorax with or without an apical stricture. Hemelytra opaque or hyaline, with clavus, corium, cuneus, membrane, and linear undifferentiated embolium; membrane with two basal cells or areoles and one longitudinal anal vein; cuneus a well-developed triangular area between the outer membrane and inner portion. Macropterous, brachypterous, and apterous forms occur within the genus or even the species. Males are usually macropterous in species with brachypterous and apterous females. Legs long and slender. Tarsi normally three-segmented, rarely two-segmented. Claws thick or slender, widely or sharply curved; with or without bristle-like arolia and pseudarolia which are of value in separating the subfamilies. Female genitalia asymmetrical; with sickle-like ovipositor. Male genitalia much used in taxonomic studies.

The members are largely herbivorous, but many species are distinctly predacious and a few are both plant and animal feeders. Many of the plant-infesting forms are most injurious to native vegetation and to cultivated crops and may fairly swarm over the hosts. The eggs are generally inserted into the hard and soft tissues of living plants. The adults may hibernate and emerge in great numbers in the spring. A considerable number of species, including the tarnished plant bug, *Lygus pratensis* (Linn.), and *Creontiades pallidus* Rambur, carry and transmit plant diseases which may result in large losses to crops. Predacious species like *Cyrtorhinus mundulus* Bred. which feeds on the eggs of the sugar-cane leafhopper in the tropical Pacific area, and the well-known aphid destroyer, *Derocoris ruber* (Linn.), of Europe, destroy noxious insects and are considered beneficial.

The family is the largest in the suborder. It is usually divided into nine to 16 subfamilies and comprises over 600 genera and 5,000 species. It reaches its highest development in the Holarctic region, where about 1,100 species are known. Some of the most important genera are *Adelphocoris* Reuter, *Atracto-*

¹ The members of this family were originally grouped with the COREIDÆ by Leach 1815, Samouelle 1819, and Stephens 1829. Other designations were CAPSINI Burmeister 1835; CAPSOIDES Spinola 1837; CAPSIDÆ Kirby 1837, Westwood 1840, Butler 1923, Schröder 1925, Weber 1930, Imms 1934, and others; MIRIDÆ Hahn 1831, Kirkaldy 1894, Reuter 1910, Van Duzee 1917, Knight 1923, Brues and Melander 1932, Hedicke 1935; PHYTO-COREIDÆ Fieber 1851.

tomus Fieber, *Calocoris* Fieber, *Camptobrochis* Fieber, *Capsus* Fab., *Dicyphus* Fieber, *Deræocoris* Kirschbaum, *Halticus* Hahn, *Helopeltis* Signoret, *Horcias* Distant, *Irbisia* Reuter, *Lygus* Hahn, *Miris* Fab., *Orthotylus* Fieber, *Phytocoris* Fallén, *Pæcilocapsus* Reuter, *Pæciloscytus* Fieber, and *Psallus* Fieber.

The genus *Lygus* is one of the commonest and most important. The tarnished plant bug, *L. pratensis* (Linn.), is one of the most abundant and injurious species and occurs over much of the Holarctic area in Europe, Asia, and North America. *L. kalmii* (Linn.) is widely distributed in Europe and Asia. It and *L. leucorum* Mayr, *L. oryzae* Matsumura, and *L. sacchari* Mats. are pests of rice and other cereals and the last also of sugar cane in Japan (Clausen, 1931). *L. pabulinus* (Linn.) is one of the commonest species in the gardens of northern Europe and ranges over much of the northern part of North America.

Deræocoris ruber (Linn.), already referred to as a beneficial predacious species, occurs over much of Europe, North Africa, North America, and South America. *Adelphocoris rapidus* (Say) is widely distributed in North America and has been reported in Japan by Clausen (1931). *Calocoris norvegicus* (Gmelin) and *C. bipunctatus* Fab. are Holarctic. *C. flavomaculatus* De Geer is the "shy bug" in the English hop fields. It is also Holarctic and has been reported in the western part of North America. *Leptopterna dolabratus* (Linn.), a grass feeder with a very strong and offensive odor, extends throughout northern Europe, northern Asia, and eastern North America. *L. holsatus* (Fab.) occurs all over Europe, northern Africa, and northern and western Asia. The garden flea hopper, *Halticus citri* (Ashmead), a small black jumping bug from 1.5–2.0 mm. long, is a general farm pest in the United States and Mexico. A similar species, *H. minutus* Reuter, occurs in Japan. *Orthotylus marginalis* Reuter and *Plesiocoris rugicollis* Fallén are serious pests in the apple orchards of Great Britain and occur on many of the trees and shrubs of that region. They also occur in much of Europe and generally feed upon alder and willow. Members of the genus *Helopeltis* are pests of tea in eastern Asia. *H. cinchonæ* Mannerheim, *H. fasciaticollis* Poppius, and *H. pallidus* Poppius occur in Japan (Clausen 1931), and the famous tea mosquito, *H. theivora* Waterhouse, lives on tea in India.

Family SALDIDÆ¹ (Amyot and Serville 1843) (Sal'di-dæ, from the Latin *saltus*, to dance, leap, jump; referring to the jumping habits of some of the insects). German, Springwanzen. Shore Bugs, Saldids.

Small delicate species varying from 3–7 mm. in length; oval, brachypterous and macropterous; pale or somber-colored; shining, punctulate, or pubescent; agile, running, flying, and jumping; living in bogs, marshes, or along the shores of fresh-water streams, ponds, and lakes, as well as on saline beaches. Head short and broad. Antennæ stout or slender, four-segmented. Eyes large. Ocelli between eyes. Rostrum long, three-segmented. Prothorax with apex almost as wide as or distinctly narrower than the head. Adults macropterous

¹ ACANTHIDES Leach 1815; ACANTHIIDÆ Stephens 1829; SALDIDES Amyot and Serville 1843; SALDIDÆ Costa 1852.

or brachypterous. Hemelytra smooth, shiny, partly transparent, often punctulate. Corium with one or two distinct veins; clavus distinct; membrane with four or five long closed cells or areoles. Legs slender. Hind coxæ long and large, femora and tibiæ long and, with the aid of the wings, permitting great elasticity in jumping and running. Tarsi three-segmented. Claws present.

The members are predacious upon aquatic and semiaquatic mites and insects and are particularly fond of the numerous gnats, mosquitoes, and other members of the order DIPTERA. The family is a comparatively small one, but the members are widely distributed throughout the world and are especially well represented in North America. There are approximately 150 species belonging chiefly to the genera *Chartoscirta* Stål, *Halosalda* Reuter, *Pentacora* Reuter, *Salda* Fab., and *Saldula* Van Duzee. The most important of these is *Saldula*, with 11 European and 17 American species. Of these *S. pallipes* (Fab.), *S. saltatoria* (Linn.), and *S. scotica* (Curtis) are Holarctic and the first of these is Nearctic as well. *S. orthochila* (Fieber) differs from most of the other members in preferring dry exposures such as sand hills, sand and chalk pits, dry heaths, and commons in Europe. *Salda littoralis* (Linn.) is also Holarctic.

Section AMPHIBICORISÆ Dufour 1833

Family GERRIDÆ¹ (Leach 1815) (Ger'ri-dæ, from the Latin *gerres*, *gerris*, a small sea fish; referring to their being small and aquatic). German, Wasserläufer. Water Striders, Skippers, Pond Skaters.

Medium-sized, linear, or short, somewhat flattened, velvety, apterous, winged, or brachypterous, long-legged, somber-colored insects which are sub-aquatic in that they skate around on the surface of the water and lay their eggs in water, the eggs being inserted into plant tissues or attached to plants and other objects in gelatinous masses. They are predacious in habits and prey upon such small insects as fall into the water or as feed or rest upon water plants. They also feed upon dead insects and other animals available. They literally walk upon the water, using the long middle and hind legs for this purpose and carrying the short raptorial forelegs in front for capturing and holding the prey. The bodies are either very slender or very short, hard, and clothed, especially on the venter, with a silvery pubescence which appears to be absolutely waterproof and enables them to cruise about in perfect safety. The head is elongated, pointed in front and widest at the eyes. Antennæ short, slender, four-segmented. Eyes large and exserted. Ocelli present, often greatly reduced. Rostrum four-segmented; segment I short. Thorax usually the

¹ Various names given to this group of insects include GERRIDA Leach 1815; GERRIDES Amyot and Serville 1843; GERRIDÆ Dohrn 1859, Lethierry and Severin 1886, Kirkaldy 1909, Reuter 1910, Van Duzee 1917, Schröder 1925, Weber 1930, Brues and Melander 1932, Hedicke 1935; HYDROMETRIDÆ Stephens 1829, Kirby 1837, Uhler 1884; HYDROBATIDA Stål 1865; HYDROBATIDÆ Uhler 1884, 1886.

The families VELIIDÆ Douglas and Scott 1865, HYDROMETRIDÆ Uhler 1884, AËPOPHILIDÆ Lethierry and Severin 1896, and MESOVELIIDÆ Reuter 1910 have been separated as distinct.

widest part of the body and almost as long as the abdomen; prothorax the longest part. Wings absent, reduced, or present. Hemelytra velvety; clavus long; corium and membrane well developed. Forelegs short, more or less raptorial. Middle and hind legs long; arising close together and distant from fore pair; hind femora extending far beyond tip of abdomen. Coxæ widely separated. Tarsi two-segmented. Claws ante-apical, rarely with arolia. Abdomen

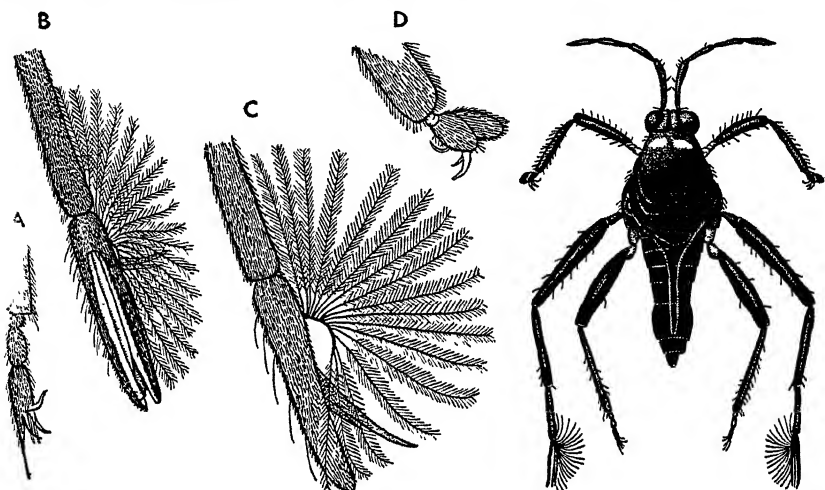


FIG. 98. A common North American water strider, *Rhagovelia obesa* Uhler. A, hind tarsus; B and C, middle tarsi; D, fore tarsus. (Redrawn from Garman, 1912.)

long and slender in the fresh-water forms or greatly reduced in the small apterous marine *Halobates*.

These insects are highly specialized for a life on the surface of the water. While they generally walk, run, or skate on the surface, they can also walk over water plants and along the shore margins, and when excited or disturbed they hop about in an erratic manner, falling as often upon their backs as right side up. The arrangement of the tarsi and claws is such as to give both buoyancy and traction on the surface of the water. These hunters glide about with an ease and speed that are astonishing. The winged species fly at night, which accounts for their wide and rapid dispersion to small and large bodies of water. The marine *Halobates*, which inhabit the surface of tropical and subtropical oceans, especially areas covered with seaweeds, have been observed hundreds of miles from land.

The life histories appear to be relatively simple. The young hatch from the submerged eggs and at once begin life on the surface. There may be from one to several generations a year. In cold regions adults may hibernate under stones, logs, and other debris around the margins of water, and in semiarid regions they may aestivate under similar objects about the dried ponds, awaiting the return of the wet season.

The family is a fairly large and cosmopolitan one. The members are most abundant on fresh water, but certain species frequent brackish water and a few live on salt water and are truly marine.

The most important genera are *Gerris* Fab., *Limnoporus* Stål, *Tenagoneus* Stål, *Metrobates* Uhler, *Trepobates* Uhler, *Rheumatobates*, Bergroth, *Halobates* Eschscholtz.

Gerris is represented in Europe by no less than a dozen species. *G. paludum* Fab. and *G. costæ* H. S. occur throughout Europe and Asia to Siberia and Turkestan. *G. najas* De Geer inhabits much of Europe and northern Africa. *G. thoracicus* Schumacher ranges into North Africa and western Asia. *G. lacustris* Linn. extends throughout Europe and northern Asia.

In North America there are 10 well-known species of which *G. remigis* Say and *G. marginatus* Say occur throughout much of the continent.

Limnoporus rufoscutellatus (Latr.), 13–17 mm. long, occurs all over Europe, northern Asia, and much of North America, ranging as far south as Arizona in this continent.

Trepobates pictus (Herrick-Schaffer) occupies middle North America with the exception of the Pacific coast.

The members of the genus *Rheumatobates* are remarkable for the hook-shaped prehensile antennæ, long middle legs, greatly enlarged hind femora of the males, and the very small abdomen. Four species occur along the Atlantic coast of North America and in the West Indies. *R. rileyi* Bergroth ranges north into New York.

The most peculiar are the species of *Halobates*, which are small apterous marine forms. The meso- and metathorax are large and fused, the middle legs are above the hind legs, and the abdomen is extremely small. They live on the surface of warm, tropical ocean waters and are encountered great distances from land. Their food habits are not definitely known but they are believed to be predacious. The eggs are laid on floating plants or debris or carried by the female (Sharp, 1899). Their marine¹ habits were first made known by B. White in 1883. Two species frequent southern North America: *Halobates micans* Esch., on the east shores and *H. sericeus* Esch. on the west.

Series II. CRYPTOCERATA Fieber 1851

Family GELASTOCORIDÆ² Kirkaldy 1897 (Gel-as'-to-cor'i-dæ, from the Greek γελαστός, laughable, + κόρις, a bug; referring, no doubt, to the amusing aspect of these insects). Toad Bugs.

Small, oval, robust, somewhat flattened, rugose bugs resembling miniature toads not only in general aspect but also in the carriage of the body, the method

¹ *Aëtophilus bonnairei* Signoret, belonging to the small family, AËTOPHILIDÆ, is largely submarine in habits and lives in crevices of and under rocks and debris, in and below the intertidal areas along the west coast of Europe, and may be submerged for at least 10 hours at a time (Butler, 1923). It is a minute species only 3 mm. long.

² These insects were first arranged with the NOTONECTARIÆ by Latreille 1802, who previously described the first genus, *Galgulus*, in 1801. Billberg used the name GALGULIDÆ

of crawling and hopping, and in their frequenting of damp and wet borders of fresh-water streams, ponds, and lakes. The colors, which vary considerably within the species, are usually dull greenish and often resemble to a remarkable degree the type of sand, gravel, or soil forming the habitat.

Head much wider than long. Antennæ short and concealed beneath the head. Eyes prominent and protruding. Ocelli present. Rostrum short, stout, four-segmented. Thorax wide. Forelegs short, raptorial; tarsi one- or two-clawed. Middle and hind legs rather short and slender. Hemelytra fused or free. Our North American species average about 6-7 mm. in length and 4-5 mm. in width. These shore bugs are quite widely distributed but are by no means as well represented and as abundant throughout the world as are most of the truly aquatic families. There are some 50 or 60 species and less than a dozen genera. Little is known concerning their biology. In some species, adults oviposit in the sand and the young live in the environment of the adults.

There are no common species in Europe and few in Asia. The most widely distributed North American species is *Gelastocoris oculatus* Fab. which ranges as far west as Arizona. *G. barberi* Torre-Bueno inhabits the Atlantic coast; *G. variegatus* Guérin the southwestern states; *Mononyx fuscipes* Guérin the southern states and Mexico; and *Nerthra stygica* Say is limited to the southeastern states. Tillyard lists nine species in Australia belonging to the genera *Mononyx* Laporte and *Matinus* Stål.

Family NAUCORIDÆ¹ (Fallén 1814) (Nau-cor'i-dæ, from the Greek ναῦς, a ship, + κόρις, a bug; referring to their aquatic habits). German, Ruderwanzen. Water Creepers, Needle-bugs, Toe-biters.

Small to medium-sized, oval or wide, flattened, leathery water bugs that inhabit running, quiet, and stagnant fresh water. Head wider than long; fitting into prothorax. Antennæ short, concealed; four-segmented. Eyes large; at basal angles of the head. Ocelli absent. Rostrum short or long; curved; usually three-segmented. Thorax wide. Macropterous and brachypterous forms.

in 1820. Following him were such similar designations as GALGULITES Laporte 1833; GALGULIDES Amyot and Serville 1843; GALGULIDÆ Westwood 1840. The latter name was in general use until Kirkaldy 1897 noted that the generic name *Galgulus* Latr. 1801 was preoccupied by *Galgulus* Brisson 1760 in AVES and for it proposed the name *Gelastocoris* as the type genus of a new family name GELASTOCORIDÆ to replace GALGULIDÆ Westwood. Subsequently, in carrying out his idea of the priority of genera in establishing family names, Kirkaldy 1897 proposed the name NERTHRIDÆ, based on the genus *Nerthra* Say 1831 as a substitute for GELASTOCORIDÆ, in which he has been supported by Reuter 1910, De la Torre-Bueno 1923, and by Brues and Melander 1932.

The name MONONYCHIDÆ Fieber 1851, based on the genus *Mononyx* Laporte 1832, has also been used by Horvath 1911, Horvath and Parshley 1927, and Imms 1930. If priority of the genus alone is to be considered, then *Nerthra* has precedence over *Mononyx*, but since Kirkaldy's substitution of *Gelastocoris* for *Galgulus* was a change in name only and not a change from the insect actually described by Latreille, it would appear that the original genus should retain priority though under a more recent name.

¹ For these insects Fallén 1814 used the name NAUCORIDEA. Leach 1815 placed them in the family NAUCORIDA under the tribe NEPIDES. Samouelle 1819 put them in the NEPADÆ. The correct designation NAUCORIDÆ, first made by Fieber 1851, has generally been followed since that time.

Hemelytra with distinct embolium and the membrane without distinct veins. The forelegs are short; raptorial, with sharp, one-segmented tarsi. Middle and hind legs with swimming hairs; two-segmented tarsi; and two claws. Abdomen without terminal respiratory appendages, air being procured at the surface and retained between the concave abdomen and the wings.¹ Female without genital appendages. Male genitalia used in classification.

These insects average about 10–15 mm. in length and almost as much in width and are truly aquatic, swimming with ease and grace. The color is

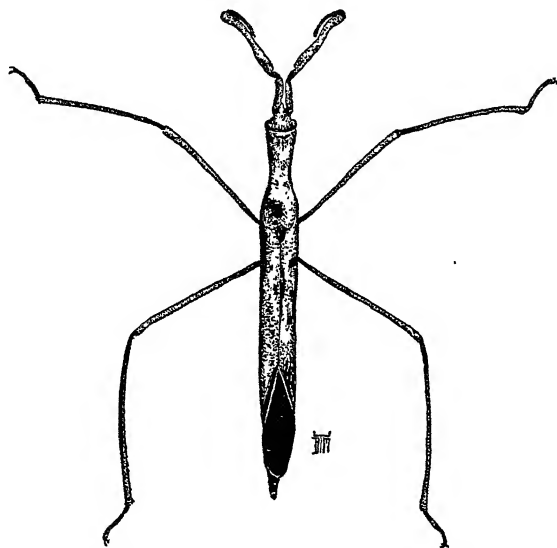


FIG. 99. The Western water scorpion, *Ranatra brevicollis* Montandon. (From *Insects of Western North America*.)

somber and consists chiefly in shades of yellow and brown. The integument is tough and smooth. They live among vegetation or rocks along the shores. By aid of a lantern, I have seen them on June nights swarming along the gravelly shores of the Eel River in California, and they are equally abundant elsewhere although not generally evident. They are active hunters, predacious in habits, and probably devour all forms of aquatic insects and other animals that can be overpowered. The adults and immature forms hibernate. The known eggs have a reticulated surface. These bugs reach their greatest development in the tropics but are quite well represented in certain temperate regions. There are about 200 described species. The most important genera are *Am-brysus* Stål, *Aphelocheirus* Westwood, *Cheirochela* Hope, *Cryphocricos* Signoret, *Heleocoris* Stål, *Laccocoris* Stål, *Limnocoris* Stål, *Naucoris* Geoffroy, and

¹ The APHELOCHEIRINÆ, raised to family rank by some workers, comprise brachypterous bugs with naked venter. They are able to take up dissolved oxygen directly from the water (Szabo-Patay, 1923).

Pelocoris Stål. The first and last are North American, with *Ambrysus signoreti* Stål and *Pelocoris femoratus* (Palisot-Beauvois) as the most widely distributed species. *Naucoris* is European and Asiatic, and *Aphelocheirus* is well represented in Japan and China.

Family NEPIDÆ¹ (Latreille 1802) (Nep'i-dæ, from the Latin *nepa*, a scorpion; from their fancied resemblance to a scorpion because of the long anal respiratory filaments). Water Scorpions.

Aquatic species variable in form from a very slender, subcylindrical type, *Ranatra*, to a wide, elongate-oval form, *Nepa*, with intermediates, *Curicta*.

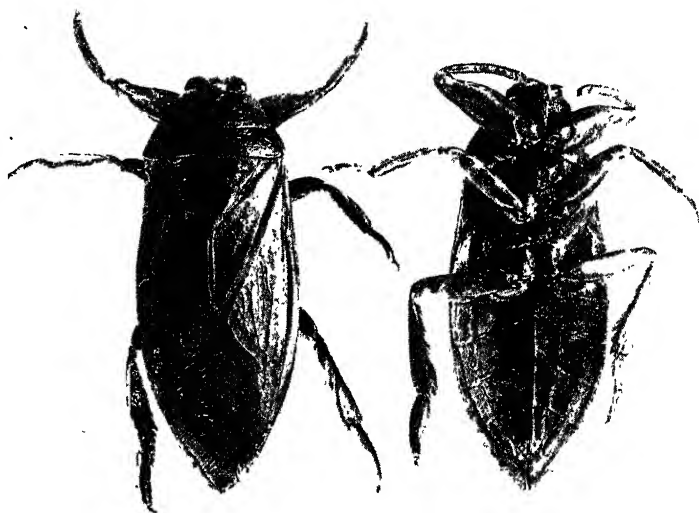


FIG. 100. The giant water bug or electric light bug, *Lethocerus americanus* (Leidy). (From *Insects of Western North America*.)

The exoskeleton is dull gray or brownish, leathery, and usually smooth. Head small, set into prothorax. Antennæ short and hidden; three-segmented. Eyes large. Ocelli absent. Rostrum short; three-segmented. Prothorax long and neck-like. Wings well developed. Hemelytra leathery; membrane with a number of distinct or indefinite veins. Legs arising from front of prothorax; forelegs short or long, raptorial, the tibiæ grooved to receive the one-segmented sickle-like tarsi which fold back into them. Middle and hind legs long and linear and hardly adapted for swimming; tarsi one-segmented and with claws;

¹ The family name of these insects has been known as NEPARIÆ Latr. 1802; NEPIDA, tribe NEPIDES Leach 1815; NEPADÆ Samouelle 1819; NEPIDÆ Fallén 1829, Stephens 1829, and others to date.

hind coxæ globular and capable of being rotated (trochalopodous). Abdomen with three pairs of false spiracles and two short or long anal respiratory filaments which form an air-breathing tube.

These insects have interesting and peculiar habits. Some stridulate by jerking back the forelegs, causing the coxæ to rub against the coxal cavities and produce a squeaking noise. Swimming is difficult, and all legs are employed: the forelegs in an up-and-down and the middle in a kicking motion. Each pair operates simultaneously as a unit, but at best the erratic swimming appears to be a struggle rather than an accomplishment. In crawling on objects under water, the normal alternations of the legs occur. The adults are from 20–50 mm. long, carnivorous, and, while they doubtless seek out eggs of various aquatic animals, they normally lie in wait for or ambuscade their prey. They come to the surface for air and at times even emerge on the ground out of the water or may be found under stones in the damp beds of recently dried streams. They fly by night. They also feign death under certain conditions when disturbed or captured. The eggs of *Nepa* each bear seven filaments at one end, whereas in *Ranatra* there are but two. They may be attached to various objects or inserted into the crevices of various kinds of rotten wood or debris on the bottom, the filaments extending into the water.

The family is rather small, consisting of some 200 species distributed throughout the world. The genera *Nepa* Linn. and *Ranatra* Fab. are practically cosmopolitan and are represented in most regions. *Nepa cinerea* Linn., the only common European species, is Palearctic. *N. apiculata* Uhler is the North American species. *N. hoffmanni* Esaki occurs in Japan. A similar genus *Laccotrephes* Stål is represented in Asia and Australia. *Ranatra* has many more species. *R. linearis* Linn., the only European species, ranges into Asia through Siberia and Turkestan. There are seven species in the United States of which *R. americana* Montandon is most widely distributed. The genus is also well represented in Japan and other parts of Asia and has two species in Australia.

Family BELOSTOMATIDÆ¹ (Leach 1815) (Be-los'to-mat'i-dæ, from the Greek βέλος, an arrow, dart, + στόμα, στόματος, mouth; referring to the sharp rostrum). German, Riesenwanzen. Giant Water Bugs, Electric Light Bugs, Fish Killers, Toe Biters.

Large flat aquatic bugs with leathery exoskeleton which are usually brownish in color. They attain a length of 3½–4 in. (up to 160 mm.) and are the largest and most powerful of all members of the order. Head broad and somewhat extended between the eyes. Antennæ short and inconspicuous; four-segmented. Eyes large and occupying much of the head. Ocelli absent. Rostrum short, somewhat curved; five-segmented. Thorax broad, somewhat triangular or narrower anteriorly. Mesothorax with or without a mid-ventral keel. Wings

¹ BELOSTOMIDA Leach 1915; BELOSTOMIDÆ Dohrn 1859, Sharp 1899, Handlirsch 1907, Van Duzee 1917; BELOSTOMATIDÆ Uhler 1886, Reuter 1910, Horvath 1911, Schröder 1925, Weber 1930, Brues and Melander 1932.

leathery, well developed; hemelytra large, with well-defined veins; basal area thick; membrane large or reduced, reticulate, the base straight or sinuous. Legs flat; fore pair short and raptorial with femora sometimes grooved for reception of tibiae and with two claws; middle and hind legs for swimming and



FIG. 101. Eggs of the giant water bug, *Lethocerus americanus* (Leidy), as deposited on a piece of wood under water.

with two-segmented tarsi and two claws. Scutellum large. Abdomen with two short, flat retractile, apical, spiracular appendages.

These remarkable bugs are veritable demons in their fresh-water habitations, where they feed upon a large variety of aquatic animals such as insects, snails, fish, tadpoles, small frogs, toads, salamanders, and any that they can overcome. They are strong swimmers and nocturnal fliers and are a nuisance in light-houses, aboard ships, and in hotels, residences, and other habitations of the tropics. In cities in temperate regions, they are often found helpless on the sidewalks and in the streets, where they are attracted by powerful lights.

The family is not a large one and consists of about 150 described species in various parts of the world. The important genera are *Belostoma* Latreille, *Benacus* Stål, *Abedus* Stål, *Lethocerus* Mayr, *Diplonychus* Laporte.

The genus *Lethocerus* contains the largest species. *L. americanus* (Leidy)¹

¹ Van Duzee (1917) lists *L. griseum* (Stål) as a synonym of this species.

is the commonest species in North America and ranges from the Atlantic to the Pacific and from Texas to Quebec. It may become 4 in. long. The giant fish killer, *L. indicus* Stål, is a huge tropical species attaining a length of 4 in. It ranges from China and India to Australia and forms a regular article of diet among natives. The South American *L. grande* (Dimmock) is probably the largest species, measuring $4\frac{1}{2}$ in. in length.

In the genera *Abedus*, *Belostoma*, and *Diplonychus*, the female glues her eggs on the backs of the males. *Belostoma boscii* Le Peletier and Serville is a widely distributed neotropical species ranging the southern part of the United States from the Carolinas into California.

Family NOTONECTIDÆ¹

(Leach 1815) (No'-to-nec'ti-dæ, from the Greek *νωτος*, the back, + *νήκτης*, a swimmer; from swimming on the back, *i.e.*, back downwards). German, Rückenschwimmer. Back Swimmers, Boat Flies.

Medium-sized aquatic insects which swim on their backs with long, oar-like hind legs. Body linear, rounded above and flat beneath, usually velvety, and varying from 3–15 mm. in length. Head inserted into the prothorax. Antennæ small and inconspicuous, four-segmented. Eyes very large, occupying most of the head. Ocelli absent. Rostrum short, curved, three- to four-segmented. Prothorax well developed, widening posteriorly. Wings usually well developed. Hemelytra with corium and clavus well defined; membrane short, without veins. Fore-legs relatively short, raptorial. Middle legs somewhat shorter and used for clinging to objects. Hind legs very long and oar-like; with or without swimming hairs; extended towards the head when at rest; without claws. Tarsi two-segmented; first segment on fore and middle legs so small as to be easily overlooked. Claws on middle and forelegs. Scutellum well developed. Abdomen

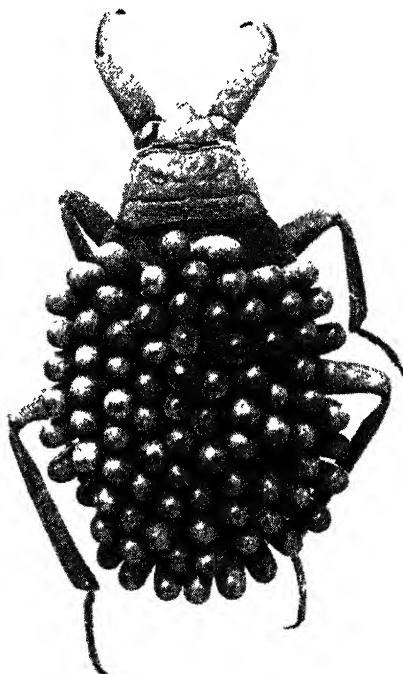


FIG. 102. The male toe-biter, *Abedus hungerfordi* De Carlo, carrying the eggs glued to his back by the female.

Antennæ small and inconspicuous, four-segmented. Eyes very large, occupying most of the head. Ocelli absent. Rostrum short, curved, three- to four-segmented. Prothorax well developed, widening posteriorly. Wings usually well developed. Hemelytra with corium and clavus well defined; membrane short, without veins. Fore-legs relatively short, raptorial. Middle legs somewhat shorter and used for clinging to objects. Hind legs very long and oar-like; with or without swimming hairs; extended towards the head when at rest; without claws. Tarsi two-segmented; first segment on fore and middle legs so small as to be easily overlooked. Claws on middle and forelegs. Scutellum well developed. Abdomen

¹ NOTONECTIDES Leach 1815; NOTONECTIDÆ Samouelle 1819 and nearly all authors since that time.

with median ventral keel and a trough on each side, covered with hair to carry air for respiration under water; long ovipositor present in some species.

Back swimmers are very common around the edges of fresh-water ponds, lakes, and streams and may be easily taken with a net or strainer. In color they differ considerably. Whilst the venter may be dark or somber the dorsum is often brightly colored, especially in tropical species. They are predatory hunters which feed upon many kinds of small animals, including tadpoles, fishes, crustaceans, and insects. They may even trouble bathers by inflicting painful bites and frequently bite when handled. They fly freely at night, leaping out of the water to take wing. Eggs are glued to or inserted into the tissues of water plants. Adults and immature stages hibernate or pass the winter in an active condition.



FIG. 103. The large backswimmer, *Notonecta insulata* Kirby. (After Woodworth from *Insects of Western North America*.)

The family is a fairly large one, being composed of 200 or more species. It reaches its highest development in tropical South America and India but is well represented in many parts of the world. The family formerly included the three subfamilies NOTONECTINÆ, PLEINÆ, and HELOTREPHINÆ, all of which have been raised to family rank. The most important genera are *Buenoa* Kirkaldy, *Notonecta* Linn., *Plea* Leach, and *Anisops* Spinola. Of these *Notonecta* is by far the most important and is cosmopolitan in distribution. *N. glauca* Linn., 14-16 mm. long, is the common European species, while in North America there are 12 species of which *N. insulata* Kirby and *N. undulata* Say are the most important. The genus *Anisops* occurs in Asia and Australia.

Family CORIXIDÆ¹ (Leach 1815) (Co-rix'i-dæ, from the Greek κόρις, a bug). German, Wasserzikaden. Water Boatmen, Water Crickets.

A family of strikingly specialized, small to medium-sized water bugs which live in fresh and brackish water. In some regions they occur in enormous numbers, and many species are attracted to lights on warm evenings. They are usually somber-colored and have a smooth, tough exoskeleton. Head peculiar in form, somewhat crescent in outline with the convex surface dorsad; overlaps pronotum posteriorly; bent backwards and under the body so that the rostrum is close to the fore coxæ. Antennæ three- to four-segmented; hidden in a recess

¹ The members of this family were early grouped with the NOTONECTIDÆ. Leach 1815 listed them as the family CORIXIDA. Dohrn first used the correct family name in 1859. This name is now generally accepted.

between the head and pronotum. Eyes triangular. Ocelli absent. Clypeus transversely striated and ridged. Rostrum short, hidden, one- or two-segmented. Pronotum often hidden under the overlapping head. Hemelytra with clavus and veined corium and membrane often completely covering the scutellum. Forelegs raptorial, short, the single tarsus or pala large, wide, longer than tibia, and furnished with one or two rows of spines or stiff bristles and with or without a single leaf-like claw or bristle; femur with a row of pegs which are engaged by the bristles on the pala to form a stridulating organ. Butler states that the palæ are rubbed over the striated clypeus to produce a chirping sound. Middle legs are long and are used chiefly for walking and clinging; tarsi two-segmented, two-clawed, and may be as long as the tibiæ. The hind legs are long and furnished with stiff swimming hairs and are used like oars, enabling the insects to swim back upwards with a rapid jerky motion. The tarsi are small, two-segmented, and furnished with two claws. These long legs are also used to clean the body. Scutellum very small. Abdomen asymmetrical in the female, one side being reduced; furnished with a strigil, a black flat comb-like organ on the dorsum of segment VI of the male which is rubbed against the underside of the hemelytra to produce a chirping or grinding noise. The palæ and strigiles furnish important characters of the males for separating species that have these organs. Males may also possess a hidden genital capsule containing claspers and genital stylets which may be useful to the systematist.

Water boatmen are very common insects to be found in fresh and brackish water in tropical and temperate regions of the world. They are admirably fitted in form and structure for a subaqueous life and have ample spaces on the surface of the body and under the wings to carry sufficient air to supply their needs for long periods. The eggs are remarkable in regularity of form and possession of a short basal pedicel. They are attached to aquatic plants and objects ¹ beneath the surface of the water and may be produced in enormous numbers. There is usually but one generation a year, at least in the temperate regions, and the adults pass the winter in an active or inactive form. In cooler regions they may bury themselves in the mud. The adults fly readily and are often not only annoying because of their presence around lights but even invade open-air swimming pools and freely bite the bathers. There is some confusion concerning their food habits. These bugs sweep all sorts of organic ooze, including both animal and plant matter, into their mouths with the palæ. They also break the cell walls and extract the contents of *Spirogyra* and other water plants. Unlike other water bugs which touch the tip of the abdomen to the surface to obtain air, corixids break the surface with the pronotum. They are often parasitized by water mites belonging to the family HYDRACHNIDÆ.

The family is rather small and consists of some 300 described species.

One of the best known species is the European water cricket, *Corixa geoffroyi* Leach, a large species 15 mm. long which lives in fresh-water ponds of Europe and North Africa, and ranges eastward into central Asia.

¹ *Arctocorixa acuminata* (Uhler), according to Comstock, usually attaches its eggs to the body of a fresh-water crayfish. It is reported from Texas and Illinois by Van Duzee.

The two remarkable North American species, *Arctocorixa mercenaria* (Say) and *A. abdominalis* (Say), occur in such numbers in Mexico as to furnish eggs for food for the natives, and the adults are captured in sufficient numbers to be dried and exported by the ton as food for domestic poultry, song birds, and fish. The former species ranges into New Mexico and California but does not occur in excessive numbers outside of Mexico.

A. interrupta (Say) occurs throughout North America from Mexico to Canada and from Maine to California. Small species of the genus *Micronecta* Kirkaldy of Australia live in fresh-water sponges (*Spongilla*) and are not abundant.

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Suborder HOMOPTERA¹ Leach 1815

This suborder comprises a large number of highly specialized and diversified families difficult to characterize as a group. The members are apterous or winged; soft and delicate or hard and elastic; naked, hairy, or covered with wax in various forms; cryptic or brightly colored; sexual or parthenogenetic; oviparous or viviparous; and varying in size from the minute adelgids and phylloxerids which are only 0.3-1 mm. long to the giant cicadas which measure up to 80 mm. to the tips of the folded wings. Practically all forms are phytophagous and mostly injurious to agriculture, but certain species have played an important part in the production of dyes, waxes, lac, and honeydew.

The suborder is usually divided into the two series AUCHENORRHYNCHA Duméril 1806, or those species having the tarsi mostly three-segmented and the rostrum arising from the ventral base of the head, and the STERNORRHYNCHA Amyot and Serville 1843 (HYMENELYTRA in this work), or those with one- or two-segmented tarsi and the rostrum appearing to arise from between the forelegs. A third series COLEORRHYNCHA is also recognized. It includes the two small families PLEIDÆ Fieber 1851 and PLOIARIIDÆ Breddin 1896-7 which have generally been placed in the HETEROPTERA. They have very short antennæ and a sheathed rostrum which apparently arises from the prosternum.

¹ These insects were called OMOPTERA by Leach in 1815. Latreille in 1817 established the name HOMOPTERA as used above.

ANATOMICAL CHARACTERS

External	Internal
<p>Size — minute, 0.3–80 mm.</p> <p>Shape — variable, globular to linear.</p> <p>Exoskeleton — smooth, naked, thin or tough; many with glands for secreting waxes or scale-like coverings.</p> <p>Colors — dull and cryptic; dark green, reddish or brilliant in tropics.</p> <p>Head — hypognathous, distinct, fitting closely into prothorax, not generally constricted behind to form neck; front venter touching fore coxae.</p> <p>Eyes — usually well developed and prominent; ocular tubercles present in some aphids and psyllids; a group of simple lenses in some forms; greatly reduced in certain groups.</p> <p>Ocelli — two or three in winged forms — absent in apterous forms.</p> <p>Antennæ — normally well developed and varying from three- to 10-segmented (rarely 25-segmented in male coccids); bristle-like in several families; rudimentary in certain coccids.</p> <p>Mouth parts — typically sucking and not differing materially from HETEROPTERA; rostrum well developed and long, very short or absent in some coccids; stylets often exceedingly long, retractile, and coiled within body; absent in some male coccids.</p> <p>Thorax — segments generally fused together and hardly distinguishable from the abdomen in aptera; well developed and clearly segmented in alates; usually the meso- and metathorax have large muscle lobes.</p> <p>Legs — very short or long and slender; chiefly employed in walking and clinging; hind legs not specially developed even in saltatorial forms.</p> <p>Hind tibiae in sexual females often swollen and with small, somewhat circular sensoria.</p> <p>Tarsi — two- or three-segmented, rarely absent or one-segmented; basal segment often much shorter than apical; one or two <i>claws</i> and <i>digitules</i> absent or present.</p> <p>Wings — absent or present; two pairs (one pair and halteres in male COC-</p>	<p>Digestive System. Mouth is simply the opening at the base of the rostrum and stylets to receive the sap into the pharynx or suction organ.</p> <p>Digestive tract — greatly modified in the various families. <i>Œsophagus</i> empties into a large crop; <i>mid-intestine</i> long and tubular and variable in its meanderings towards the anus; often coiled Malpighian tubes, when present two, three, or four in number (absent in APHIDOIDEA); situated anteriorly; filter chamber present; <i>mid-intestine</i> is closed sac in DI-ASPIDIDÆ.</p> <p>Salivary glands — usually two or three pairs with salivary pump present.</p> <p>Wax glands — prevalent and variable in most members; wax excreted in many forms as powder, threads, rods, plates, flocculence, or a firm mass surrounding the bodies.</p> <p>Circulatory System. Chambered dorsal vessel present or indistinguishable. This system needs extensive investigation.</p> <p>Respiratory System. Well developed in most families.</p> <p>Spiracles — normally nine to 10 pairs; reduced to two thoracic pairs in certain coccids.</p> <p>Nervous System. Variable; one, two, or three ganglia present.</p> <p>Reproductive System. Remarkably efficient and permitting the production of enormous numbers of eggs and young. Females sexual or parthenogenetic; oviparous or viviparous. Number of <i>ovarioles</i> varies from one or two, eight or nine, 40 or 50. From two to three tubular or globular <i>accessory glands</i> may be present but are absent in some coccids (Imms). Male organs simple.</p>

ANATOMICAL CHARACTERS—*Continued*

<i>External</i>	<i>Internal</i>
<p>CIDÆ); membranous; strong or fragile; often with simple and reduced venation; fore pair largest and sometimes thickened and pigmented; with couplings; folded flat or roof-like over back.</p> <p><i>Spiracles</i> — usually a pair on each thoracic segment or a pair on each of the pro- and metathoracic segments.</p> <p><i>Abdomen</i> — distinctly or indistinctly segmented, number of segments variable up to nine, 10, or 11; sounding organs present at base in most male cicadas; tubercles, honey tubes, and wax glands present in specialized groups; <i>pygidium</i> specialized in some families and valuable in separating species. <i>Sex organs</i> generally well developed and conspicuous in CICADIDÆ, ovipositor common.</p> <p><i>Spiracles</i> — few or absent on abdomen in some female coccids; seven pairs in most families.</p>	

CLASSIFICATION OF THE HOMOPTERA

(Includes the important families only)

- A. Series AUCHENORRHYNCHA Duméril 1806
- I. Superfamily FULGOROIDEA Kirkaldy 1907
- | | |
|--------------------------|-------------------|
| 1. Family TETTIGOMETRIDÆ | 5. Family CIXIIDÆ |
| 2. " FULGORIDÆ | 6. " FLATIDÆ |
| 3. " DICTYOPHORIDÆ | 7. " ISSIDÆ |
| 4. " DELPHACIDÆ | 8. " RICANIIDÆ |
- II. Superfamily CICADOIDEA Ashmead 1904
- | | |
|--------------------|------------------------|
| 9. Family CICADIDÆ | 14. Family CICADELLIDÆ |
| 10. " MEMBRACIDÆ | 15. " GYPONIDÆ |
| 11. " MACHÆROTIDÆ | 16. " BYTHOSCOPIIDÆ |
| 12. " CERCOPIDÆ | 17. " JASSIDÆ |
| 13. " ÆTHALIONIDÆ | |
- B. Series HYMENELYTRA Latreille 1825 (PHYTOPHTHIRES Burmeister 1835)
- III. Superfamily CHERMOIDEA New Combination
- | | |
|--------------------------------|--------------------|
| 18. Family CHERMIDÆ (PSYLLIDÆ) | 19. Family LIVIIDÆ |
|--------------------------------|--------------------|
- IV. Superfamily ALEYRODOIDEA Handlirsch 1903
20. Family ALEYRODIDÆ
- V. Superfamily APHIDOIDEA (Latreille 1802) Handlirsch 1903
- | | |
|----------------------------------|-------------------------|
| 21. Family ADELGIDÆ (CHERMESIDÆ) | 23. Family ERIOSOMATIDÆ |
| 22. " PHYLLOXERIDÆ | 24. " APHIDIDÆ |

VI. Superfamily COCCOIDEA Handlirsch 1903

25. Family MARGARODIDÆ

26. " ORTHEZIIDÆ

27. " LACCIFERIDÆ
(TACHARDIIDÆ)28. " KERMIDÆ (KERMITIDÆ,
KERMESIDÆ)

29. Family DACTYLOPIIDÆ

30. " PSEUDOCOCCIDÆ

31. " ACLERDIDÆ

32. " ASTEROLECANIIDÆ

33. " COCCIDÆ

34. " DIASPIDIDÆ

A. Series AUCHENORRHYNCHA Duméril 1806

I. Superfamily FULGOROIDEA¹ Kirkaldy 1907

Family FULGORIDÆ Latreille 1807 (Ful-gor'i-dæ, from the Latin *Fulgora*, the goddess of lightning, or *fulgor*, lightning). Lanternflies.

The members are characterized by frequently having the head rounded or only slightly or greatly prolonged; the antennæ three-segmented, variable in

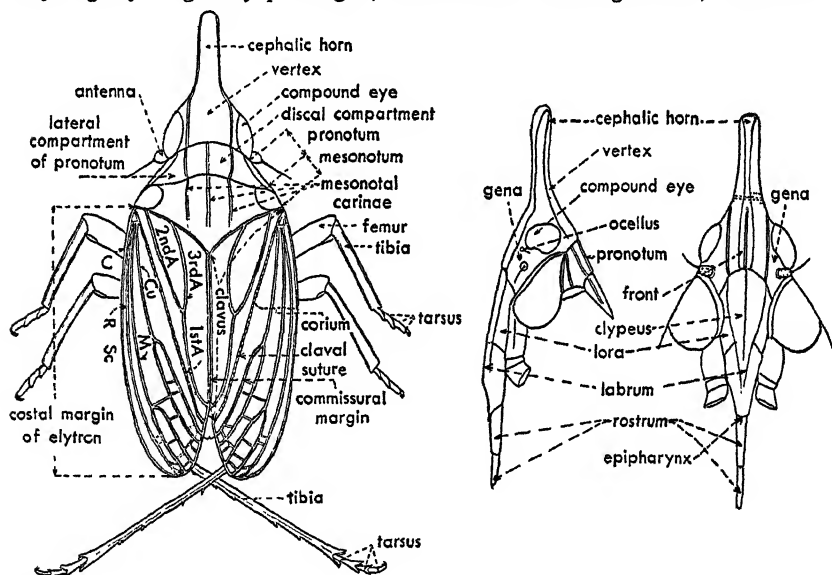


FIG. 104. The fulgorid, *Scolops angustatus* Uhler, showing important external characters. (Drawing by Garman, *Hemiptera of Connecticut*, 1923.)

form, arising from beneath the eyes and terminating in a filament; normally two ocelli, rarely three or none, located usually in cavities beneath or near the eyes. Wings membranous and folded roof-like, vertically or horizontally; aborted, short, or longer than the body.

A family of mostly subtropical and tropical species which vary in size from the small southern European *Trypetimorpha fenestrata* Costa which is only

¹ The superfamily FULGOROIDEA is now divided into as many as 18 families.

3–3.5 mm. long to the magnificent nonluminous South American lanternfly or peanut bug, *Laternaria phosphorea* Linn., with a wing expanse of 153 mm. (about 6 in.).

These insects are often most peculiarly and even grotesquely formed, beautifully colored, and adorned with filaments of white wax that resemble tails. All are plant feeders.

The most important closely related families are as follows:

Family DICTYOPHORIDÆ Spinola 1839.

The members of this family have narrow wings and greatly prolonged heads. The genera *Dictyophora* Germar and *Scolops* Schaum are common in many parts of North America. The family is widely distributed.

Family DELPHACIDÆ Spinola 1839.

This family comprises small species with a large movable apical spur on the hind tibiae. It owes its importance chiefly to the great economic rôle of the sugar-cane leafhopper, *Perkinsiella saccharicida* Kirkaldy, a species native to northern Australia which, about 1897, was introduced into the Hawaiian Islands, where it did great damage in 1903 as a serious pest of sugar cane until it was finally brought under control through the introduction of natural enemies.

Family CIXIIDÆ¹ Spinola 1839 (Cix-i'i-dæ; derivation unknown).

A family of small primitive insects which are elongated in form, somewhat depressed; head only slightly or not prolonged in front; antennae arise below

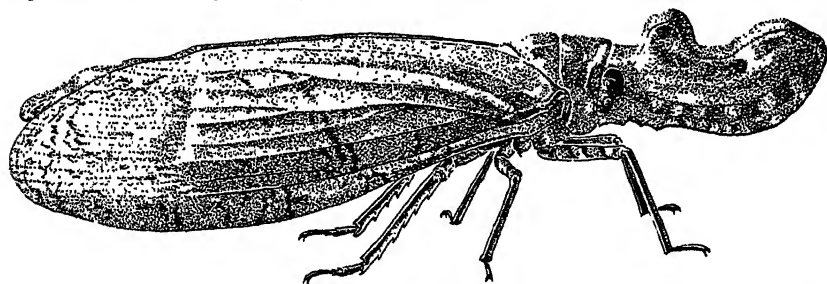


FIG. 105. Serville's lanternfly, *Laternaria servillei* Spinosa, of Brazil. The shape of the head gives rise to the common name "peanut bug." Although believed to emit light it is nonluminous.

the eyes, the flagellum not segmented; two or three ocelli. Rostrum short, the last segment of the labium longer than wide, sides of clypeus not keeled, wings rather broad and often with fuscous markings, folded roof-like; tegulae present; fore wings not reticulated apically, costal area absent, rarely coriaceous, pre-costal area very small or absent, without veinlets, two anal veins usually

¹ CIXIOIDES Spinola 1839, Walker 1851 (in part); CIXIIDA Stål 1851; CIXIIDA Stål 1866, Uhler 1884; CIXIIDÆ Melichar 1903, Fowler 1904, Oshanin 1912, Brues and Melander 1932, Haupt 1935. For many years grouped with the family FULGORIDÆ.

present. Middle coxæ elongate, widely separated; hind coxæ fused with metasternum. Hind tibiae without movable spur. Scutellum somewhat rhomboidal. Abdominal tergites 6, 7, 8 without wax pores. Females often with tails on either side of the oviduct.

The members are chiefly plant feeders and are able to jump rapidly. Although abundant in the temperate regions, they reach their highest development in the tropics. The most important genera in the Holarctic region are *Bothriocera* Burm., *Cixius* Latr., *Helicoptera* A. and S., *Hyalesthes* Signoret, *Myndus* Stål, *Æcleus* Stål, and *Oliarus* Stål.

Family FLATIDÆ Spinola 1839.

A family of curiously formed moth-like species which frequently have large triangular wings held roof-like close to the body, giving a decidedly laterally compressed appearance. They are further distinguished by the cross-veined costal cell and granulated clavus. The temperate forms are usually somber in color while the tropical species are among the brightest and most colorful of insects, some species being dimorphic in coloration.

II. Superfamily CICADOIDEA Ashmead 1904

Family CICADIDÆ¹ (Latreille 1802) (Ci-cad'i-dæ, from the Latin *cicada*, a tree cricket). German, Singzikaden. French, Cigales. Cicadas, Harvest Flies.

The cicadas or harvest flies are medium to large, robust insects varying in size from the small *Okanagana minuta* Davis of western North America which is only 16 mm. long to the large *Pomponia adusta* (Walker) of Java which measures 80 mm. in length. They are among the most interesting of all insects and are characterized by having wholly membranous wings; three ocelli in a triangle between the eyes; the rostrum long and arising plainly from the head; and small bristle-like five- to six-segmented antennæ arising from a short basal segment; fore femora thickened and usually spined ventrally; tarsi three-segmented; claws without empodia; males with few exceptions having a well-developed tympanum sounding organ on each ventral side of the base of the abdomen. The adults vary much in color and while the temperate species are rather somber, tan, gray, or very dark with green, red, brown, and white markings, the tropical species may be arrayed in brilliant hues, one Chinese species being red and black.

These insects inhabit chiefly areas partly forested with deciduous trees and shrubs, although certain species live among grasses and weeds in more or less forested regions. They are everywhere known by the loud, shrill, monotonous mating call of the male which rings forth on hot sunny days in late spring and

¹ Latreille grouped these insects as CICADARIÆ in 1802 and Leach erected the tribe CICADIDES and the family CICADIDA in 1815. The latter was changed to CICADIDÆ by Samouelle in 1819 and has been generally accepted for this homogenous group of remarkable insects.

throughout much of the summer.¹ In years of abundance the noise produced by the thousands of males is almost deafening, and the females may do considerable damage to wild and cultivated shrubs and trees by inserting their eggs and thus killing the small branches.

But this is not the only sound of the cicada. Certain species produce intermittent buzzings, whirrings, and chirpings, and a considerable number of both

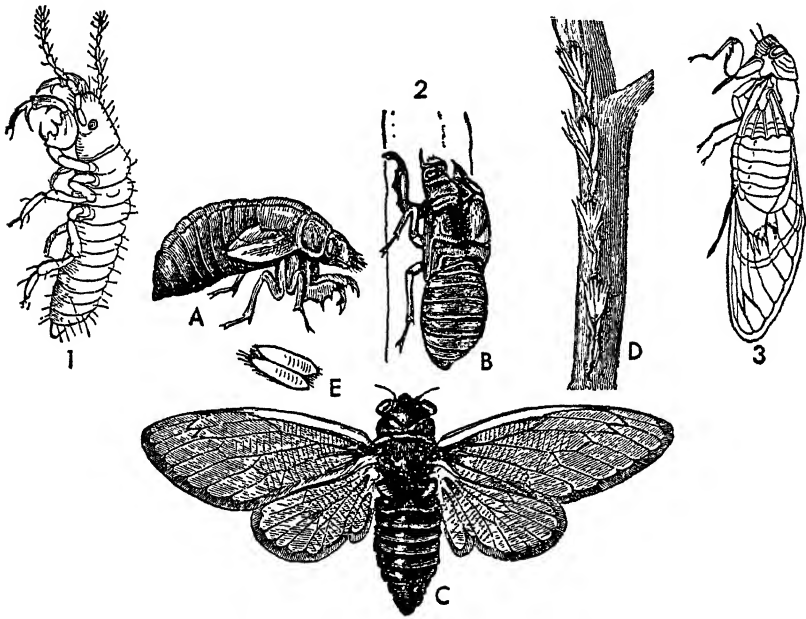


FIG. 106. An early illustration of the periodical cicada, *Magicicada septendecim* (Linn.). 1, 1st instar; 2, A, mature nymph; B, cast nymphal skin or exuvia; C, adult with wings spread; D, egg-punctures in twig; E, eggs removed from punctures; 3, adult with wings folded. (After Riley, 1869.)

sexes click by beating the fore wings together beneath the body or against the branches upon which they rest. In some species singing begins at 60°F, and as long as the temperature is sufficient and the air still, their songs may continue until sunset or even into the night. When captured, while singing or even when still, certain species emit high-pitched notes not unlike a shriek or a call for help. *Cacama crepitans* (Uhler) of California is such a species, and even when removed from the net and held they will cry out when slightly pressed. I have induced others to sing by carrying them around and occasionally pressing them. When disturbed, adults frequently flutter to the ground and, if unable to get

¹ In China and Japan male cicadas are captured by means of a small amount of bird lime at the end of a long pole or by means of a net and are kept in very small, artistic cages indoors where they delight the human occupants with their fervent mating calls.

away quickly, will feign death to escape detection. In such cases they do not regain activity for many minutes.

The male is distinguished from the female by the *ædeagus* or dorsal, apical, irregular, and erect intromittent organ whereas the female has a large, spike-like, protrusile ovipositor. In feeding the adults frequently and forcibly discharge jets of watery honeydew which may fall in considerable quantities from trees heavily infested by these insects.

The females are attracted by the song of the males, and when they alight close by, the males cease singing and begin a silent courtship. The elongated eggs are normally inserted into the stems of small plants, the seed stalks of annuals and perennials, and mostly into the hard, dead or living twigs and branches of shrubs and trees. In ovipositing the female chisels downwards through the bark and into the hard wood or pith and inserts the eggs in more or less continuous rows as shown in the accompanying illustration.

When the eggs hatch, in a very short time or in from 2 to 6 weeks, the young drop or crawl to the ground. They then begin a subterranean life, feeding upon the roots of various plants. This period may require from 2 to 5 years in most species or from 13 to 17 years in the case of the famous seventeen-year locust or periodical cicada, *Magicicada septendecim* (Linn.) (*Tibicina*), of the middle and eastern United States. In the middle and northern reaches of its distribution 17 years are required to complete the life cycle, while in the southern states only 13 years are necessary.

The larvæ or nymphs are most peculiar-looking insects, pale in color, awkward in movements, and characterized chiefly by the large, toothed, fossorial forelegs. We can gain little from a description without first examining the accompanying illustration.

When fully matured, the nymphs emerge from the soil, climb any convenient shrub or tree, and attach themselves firmly, after which the dorsal line in the integument parts and the adults emerge to feed, sing, mate, oviposit, and perish before the coming of winter.

The family is composed of some 1,500 species and is cosmopolitan in distribution. In Great Britain there is but a single species, *Cicadetta montana* Scopoli, which occurs throughout much of middle Europe. Altogether there are less than a dozen common species in all of Europe. According to Myers (1929) the cicada of the classics and of the eminent French entomologist Jean Henri Fabre (1823–1915) is *Tibicen plebeia* Scopoli. These two species, together with *T. hæmatodes* Scopoli and *Cicada orni* Linn., are the commonest European representatives. *T. hæmatodes* is known as the vineyard cicada. It starts to sing at the beginning of the grape harvest early in August and stops by tradition on Holy Friday in the middle of October.

One of the most remarkable and interesting species is the Chinese blistering cicada or Chu-ki,¹ *Huechys sanguinea* (DeGeer), of China, Japan, and southern Asia. It is also called the "red medicinal cicada" because of its brilliant red

¹ According to Gaines Liu (1930), Chu-ki is a fulgid, *Lycroma delicatula* White, which is the real medicinal insect and not the cicada, has as been thought for many years.

and black colors and its uses as a vesicant, and the "little cock of the ailanthus tree" because it is so often found on this host. It has a peculiar odor. The oil cicada, *Graptopsaltria colorata* (Stål), of Japan, gets its common name because its song sounds like very hot frying fat. *Meimuna opalifera* Walker, 45 mm. long, also of Japan, sings in autumn and has a note like a songbird.

The great Borneo cicada, *Pomponia imperatoria* (Westwood), 3 in. long and with a wing expanse of 8 in., sings in the evening. It is used for food in the Malay Peninsula, as are many species of cicadas elsewhere in the world.

Cicadas are abundant in Australia, 180 species being known there. The most primitive members of the family, *Tettigarcta tomentosa* F. B. White and *T. crinita* Distant, hairy brown species the males of which have no sound organs, occur there; the former in Tasmania and the latter in Victoria. The curious bladder cicadas, including the green *Cystosoma saundersi* Westwood, have inflated abdomens. Three species, the double drummer, *Thopha saccata* Fab., *Henicopsaltria eydouxi* Guérin, and *Cyclochila australasia* Donovan, have a wing expanse of 127 mm. or about 5 in.

There are approximately 200 species in North America. Of these the periodical cicada, *Magicalcica septendecim* (Linn.), a black and tan species with red eyes, 30 mm. long, is by far the most interesting and important species because of its long subterranean larval period and economic importance previously mentioned. The dog-day cicada or lyreman, *Tibicen linnei* Smith and Grossbeck (= *tibicen* Germar), is a large robust green and black species 32 mm. long which has a shrill, noisy song late in summer. *T. auletes* (Germar), with a wing expanse of 115 mm., is the largest, and *Okanagana minuta* Davis, 15 mm. long, is one of the smallest species in North America. *O. cruentifera* (Uhler) and *Diceroprocta apache* (Davis) are southwestern arid species which oviposit in date palms as well as in their native desert hosts. Putnam's cicada, *Platypedia minor* Uhler, 17 mm. long, is a common western species which makes a clicking noise with the wings. It and a number of other species in the same genus oviposit in fruit trees and in many native trees and shrubs.

Family MEMBRACIDÆ Germar 1821 (Mem-brac'i-dæ, from the Greek μέμβραξ, a kind of cicada). Treehoppers, Devilhoppers.

Small bizarre insects having the head vertical; the pronotum enlarged so as to project over the head and backwards over the scutellum or even over the abdomen, and queerly ornamented with spines, hooks, and balls in tropical species; antennæ arise below and slightly in front of the eyes, the flagellum many-segmented; two ocelli between the eyes; wings membranous; tibiæ angular; posterior coxæ transverse. The adults are various shades of yellow, green, brown, gray, black, or brilliant colors and are active or sluggish and walk, fly, or jump as occasion demands. They will sometimes move behind a leaf or around a branch to avoid capture and often occur in groups or in rows. The immature forms are often as strange-appearing as the adults for, while they lack the differentiated pronotum, the tergites are often rounded and ornamented with simple and plumose spines.

These insects inhabit shrubs and trees chiefly but are also to be found in open fields on various weeds, grasses, and similar perennial plants upon which they feed and into whose tissues the females insert their somewhat club-shaped eggs by means of a chisel-like ovipositor. The place of oviposition may be the bark or wood of a tree, the midrib of a leaf, or the stem of a succulent plant, and the eggs may be arranged in irregular groups or in rows in series of three to six or more.

In the temperate regions the complete life history of five instars may require six weeks, and there are from one to three broods a year. In the tropics there is greater rapidity in growth and more continuous breeding. Most species excrete honeydew, but only certain species attract ants which wait upon them much as they do upon aphids. The members are more or less restricted in their feeding to certain species or families of plants, and many have definite alternating hosts upon each of which they spend a certain part of the year. As a group these insects are not particularly injurious. In the cooler limits of their distribution hibernation may be in the egg, nymph, or adult stage. The family reaches its greatest development in the tropical areas of North and South America, Africa, and Asia, and its zenith in South America. There are about 350 genera and a great many species.

In Europe there are but two common genera, *Centrotus* Fab. and *Gargora* Amyot and Serville, and two species, *C. cornutus* (Linn.) and *G. genistæ* (Fab.). In North America there are no less than 45 genera and 200 species. The most important genera are *Carynota* Fitch, *Ceresa* A. and S., *Cyrtolobus* Goding, *Glossonotus* Butler, *Stictocephala* Stål, and *Thelia* A. and S. The buffalo tree hopper, *Ceresa bubalus* (Fab.), is the best known species although many others are common and widely distributed. There are 40 species in Australia, including many curious forms. Among them is *Lubra regalis* Goding which has large, heavy pronotal processes resembling horns. In most of the species pronotal horns or projections are present.

Family CERCOPIDÆ¹ (Leach 1815) (Cer-cop'i-dæ, from the Greek κέρκος, tail, + ψ, appearance). German, Schildzirpen. Froghoppers, Spittlebugs, Cuckoo Spit Insects.

These small insects derive their common names from the squatty, frog-like appearance of the young and adults and from the fact that the immature forms of certain genera are surrounded with and live in a mass of white froth or spittle-like medium which is expelled from the anus.

The members are closely related to the CICADIDÆ and are distinguished by having but two ocelli; smooth tibiae, the hind pair with one or two stout fixed spines and a group of smaller ones at the apex; and lateral glands on abdominal segments VII and VIII. They are all plant feeders and are cosmopolitan in distribution but most abundant in the tropics. The most important Holarctic genera are *Aphrophora* Germar, *Cercopis* Fabr., *Clastoptera* Germar,

¹ This family as formerly conceived has recently been raised to superfamily rank with four families of which one retains the above name.

Lepyronia Amyot and Serville, and *Philænus* Stål. The most abundant species in Europe is *Philænus spumarius* (Linn.), a small brownish species 5–6 mm. long, which in some areas covers the low vegetation with spume. *Aphrophora* is well represented in Japan and North America. *A. quadrinotata* Say, *A. parallela* (Say), and *A. saratogensis* (Fitch) are widely distributed east of the Rocky



FIG. 107. "Spittle" on a pine twig produced by the spittlebug, *Aphrophora permutata* Uhler. (From *Insects of Western North America*.)

Mountains in North America. One of the most remarkable members of the family is *Ptyelus goudoti* Benn. of Madagascar which exudes almost pure water in such quantities as to cause the invested hosts to be called "weeping trees."

Members of the closely related family MACHÆROTIDÆ Kirkaldy are known as tube-forming cercopids from the habits of the young in constructing

tubes attached to the branches within which they live surrounded by froth. *Machærota guttigera* Westwood of Ceylon and members of the genera *Pectinariophyes* Kirkaldy, and *Polychætophyes* Kirkaldy, infesting eucalyptus in Australia, are representatives. Others occur in Africa. The sugar-cane frog-hopper, *Tomaspis saccharina* Distant, causes froghopper blight of sugar cane in Trinidad.

Family CICADELLIDÆ¹ (Latreille 1802) (Ci'ca-dell'i-dæ, from *cicadella*, diminutive of the Latin *cicada*, a cicada or tree cricket; literally a small cicada). Leafhoppers, Sharpshooters.

The members of this large family are small, slender insects with minute, bristle-like antennæ inserted in front of and between the eyes; usually with two ocelli; the hind tibiæ with a double row of spines, the chief distinguishing characteristic of the family. The front wings are somewhat thickened and often brightly colored to match the head and prothorax. As the common names imply, they are active jumpers although the adults also fly freely. Both young and adults have the characteristic habit of running sidewise. All are plant feeders and pierce and suck out the juices, causing a drying-up and wilting of the tissues. In addition, many species are carriers of plant diseases such as hopperburn, tipburn, curly leaf, blight, mosaic, and other bacterial and fungous diseases, and cause great losses to certain agricultural crops.

The winter is usually passed in the egg stage, although adults in many species and nymphs in a few species hibernate in grasses, weeds, or trash. The small, whitish, elongate, slightly curved eggs are inserted in tender or hard plant tissues in the fall and spring, and the wingless nymphs after four or five molts grow to maturity in 18 to 50 days so that from one to six broods may appear before the next winter. Of the large number of known species the great majority feed upon wild grasses, weeds, flowers, shrubs, and trees. A number of native species has also gone over to cultivated plants. They are now serious pests while a few are introduced Old World species of well-known destructive habits.

The group which formerly constituted this family is now divided into at least 16 distinct families by some modern authors. The whole group is a very large one and consists of hundreds of genera and thousands of species distributed throughout the entire world. The members of the family as now defined have the ocelli dorsally placed.

The most important North American genera are *Cicadella* Latr., *Dræculace-*

¹ There has been a noticeable lack of uniformity in the name of this family. The important family names have evolved as follows: CICADELLÆ Latreille 1802; CICADELLINA Burmeister 1835; CICADELLIDÆ Latr. 1850; TETTIGONITÆ Spinola 1850; TETTIGONIDÆ Uhler 1876; JASSIDES Amyot and Serville 1843; JASSINA Stål 1858; JASSIDÆ Fieber 1866. Europeans generally accept the name JASSIDÆ (Imms 1934, Haupt 1935, Perrier 1935). The genera giving rise to these family names were established as follows: *Tettigonia* Réaumur 1740 (pre-Linnæan), Olivier 1789, Latreille 1801; *Cicadella* Latreille 1817 (new name for *Cicada* Fab. 1775); *Jassus* Fab. 1803.

The modern concept of a large number of distinct families to replace the former one has largely eliminated the difficulties of nomenclature.

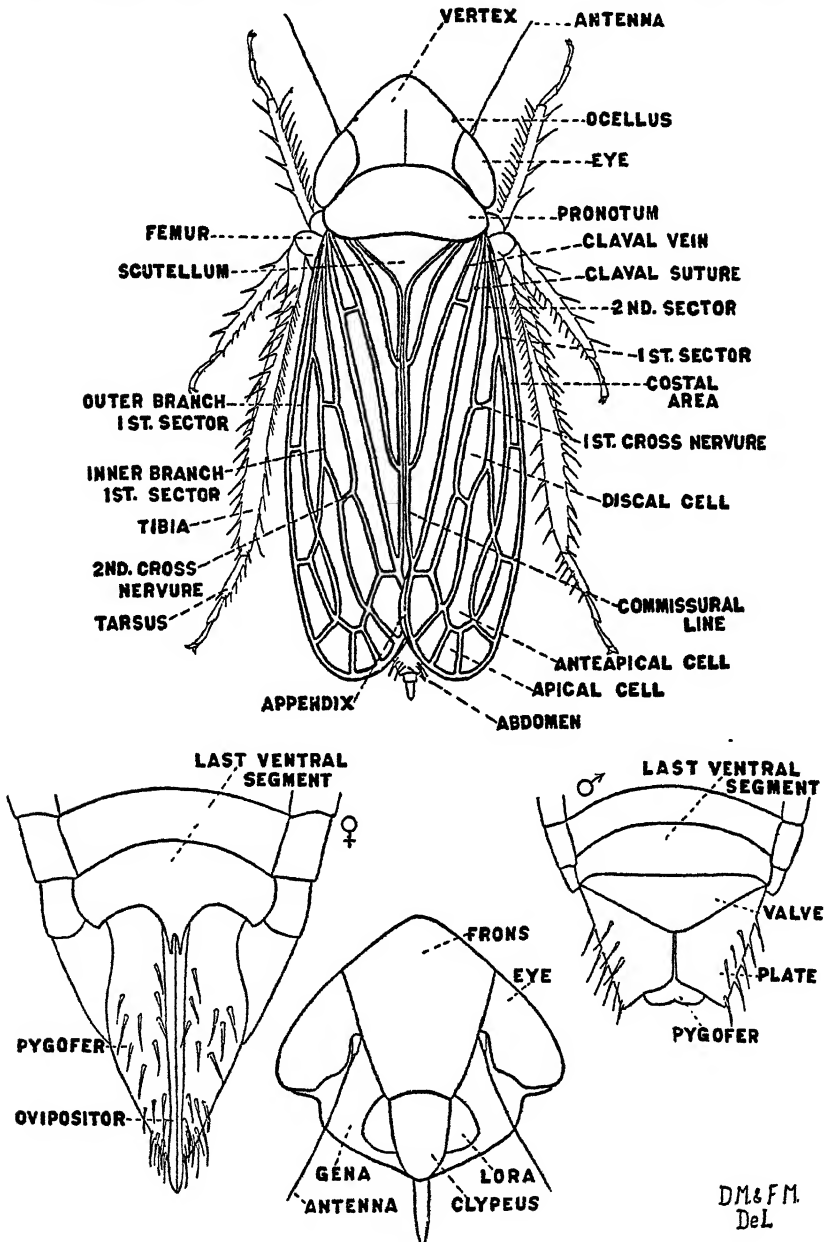


FIG. 108. A leafhopper, *Deliocephalus configuratus* Uhler, labeled to show external structures. (After DeLong, *Hemiptera of Connecticut*, 1923.)

phala Ball, *Graphocephala* Van Duzee, *Kolla* Distant, and *Oncometopia* Stål. Many species are important pests of agricultural crops throughout the world.

Family JASSIDÆ¹ Stål 1858 (Jas'si-dæ, from the Greek *Ίασσος*, a town in Caria, now Askem). Leafhoppers.

This is the largest and most important family of leafhoppers. The members are small, usually slender species having the ocelli on the edge of the vertex or on the margin between the vertex and the frons. Certain species often fairly swarm over vegetation and spread destruction to the host plants. Cultivated plants in no part of the world are free from their presence.

Among the very many large and well-known genera may be mentioned *Acucephalus* Germar, *Chlorotettix* Van Duzee, *Cicadula* Zetterstedt, *Deltocephalus* Burmeister, *Dicraneura* Hardy, *Empoa* Fitch, *Empoasca* Walsh, *Erythroneura* Fitch, *Euscelis* Brullé, *Eutettix* Van Duzee, *Jassus* Fab., *Phlepsius* Fieber, *Platymetopius* Burm., *Scaphoideus* Uhler, *Thamnotettix* Zett., and *Typhlocyba* Germar. Although many species like the rice leafhoppers belonging to the genera *Cicadula*, *Deltocephalus*, and *Nephotettix* in the Orient; the grape leafhopper, *Erythroneura comes* (Say) in North America, and countless similarly destructive species are exceedingly injurious to plant life, perhaps the most important species are those which transmit diseases of plants like the beet leafhopper, *Eutettix tenellus* (Baker), which transmits the serious curly leaf disease of sugar beets in western North America.

B. Series HYMENELYTRA Latreille 1825 (PHYTOPHTHIRES Burmeister 1835)

III. Superfamily CHERMOIDEA New Combination

Family CHERMIDÆ² (Fallén 1814) (= PSYLLIDÆ Latreille 1807) (Cher'mi-dæ, from the Arabic and Persian *qirmiz*, crimson, carmine; referring to the crimson dye-producing insect of that name). Jumping Plant Lice, Psyllids, Lerp Insects.

The members of this small family are easily separated from the other families of this order. The adults appear like miniature cicadas but are about the size of aphids or plant lice. They have the ability to jump and are therefore known as jumping plant lice. Like the aphids, the rostrum arises far back on the venter of the head, but the wing venation readily separates the two families. The antennæ are nine- to 10-segmented; the tarsi two-segmented; three ocelli; and a complicated closing device for the two thoracic and three abdominal spiracles. The eggs are elongate and usually attached by a short stipe. The nymphs are very characteristic, being oval or slightly elongated, flat with conspicuously

¹ See discussion of family names under CICADELLIDÆ.

² The genus *Chermes*, erected by Linnæus in 1758, included all the then known species. The family CHERMIDES was established by Fallén in 1814, but the form of the word has been corrected to the above. The family name PSYLLIDÆ, erected by Latreille in 1708 and based on the genus *Psylla* Geoffroy 1762, has been discarded because the latter is a synonym of *Chermes*. Kirkaldy 1905 erected the genus *Psyllia* with *pyri* Linn. as type to include certain species included in *Psylla*.

large wing pads, and often with a marginal fringe around the body. They may be naked, hairy or covered with wax and excrete quantities of honeydew. Some of the species have been imported on ornamentals from foreign countries.

These insects are widely distributed in the temperate regions and are notably abundant and varied in Australia, where 80 species of these so-called lerp

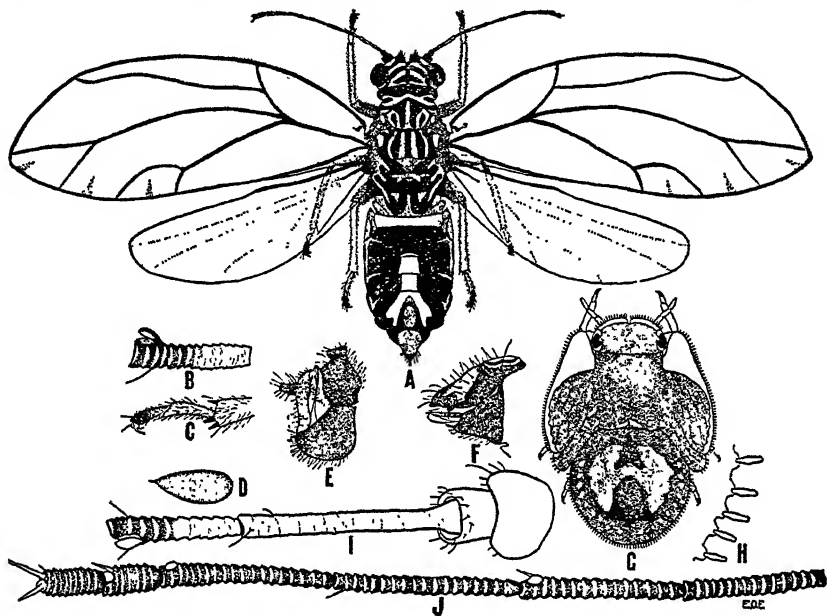


FIG. 109. The tomato or potato psyllid, *Paratrioza cockerelli* (Sulc). A, adult female; B, antennal segment IV showing peculiar sensorium; C, tarsus; D, egg; E, genitalia of male; F, genitalia of female; G, nymph; H, marginal fringe of same; I and J, antenna. (From *Insects of Western North America*.)

insects replace the aphids. They often occur in very great numbers on eucalyptus, acacia, and other native plants. All secrete quantities of honeydew and a few produce galls on the leaves. The sugar lerp insect, *Spondyliaspis eucalypti* Dobson, excretes sufficient amounts of lerp honey to be collected for food by the aborigines. The brilliant red *Cretis longipennis* Walker, 6 mm. long, is one of the largest Australian species.

The pear psylla, *Psyllia pyricola* Förster, 1.5 mm. long, is a serious pest of pear trees, and the apple sucker, *P. mali* Schmidberger, attacks apples in Europe and eastern North America. *P. buxi* Réaumur forms miniature cabbage-shaped galls on boxwood, and *Trioza alacris* Flor curls the leaves of the laurel or sweet bay in Europe and other parts of the world where it has been introduced. The nymphs of the latter secrete quantities of white cottony wax over their bodies. The tomato psyllid, *Paratrioza cockerelli* (Sulc), is of importance because it disseminates a disease of potatoes in western North America. The

olive psyllid, *Euphyllura olivina* Costa, is a pest of olives in the Mediterranean Basin.

IV. Superfamily ALEYRODOIDEA Handlirsch 1903

Family ALEYRODIDÆ Westwood 1840 (= **ALEURODIDÆ**) (Al'ey-rod'i-dæ, from the Greek ἀλευρώδης, like flour; from the white waxy covering of the wings and bodies). Whiteflies, Aleyrodids.

The white flies are very small insects from 1-3 mm. long, the adults of which are characterized by having the body and wings covered with a fine, whitish, powdery wax giving an opaque appearance. The compound eyes are somewhat reniform, and there are but two ocelli, one near the front of each compound eye. The antennæ are well developed and usually seven-segmented; the rostrum arises far back on the underside of the head; the tarsi are composed of two nearly equal joints terminating in two claws which have a spine or pad known as a *paronychium* between them. There are two pairs of wings which are held almost flat or slightly roof-like over the body at rest; the venation is simple.

The eggs are small, oval, and attached to the plants by a short or long pedicel. The surface is smooth or sculptured, and the color varies from yellow to black. They are normally attached to the undersides of the tender leaves and may be arranged in circles or distributed over the entire surfaces. They are so small as to be scarcely seen without the aid of a lens, and are often covered with the whitish wax from the bodies of the females.

The newly hatched young are motile but lose the legs and antennæ with the first molt. The intermediate forms are soft, oval, flat, and much resemble the soft unarmored scales. The bodies vary greatly in color and are naked or covered with fine or thick, white, waxy plates or cottony material. There is also often present a fringe of conspicuous, white wax plates or obscure transparent wax filaments. The most characteristic thing, however, is the *anal vasiform orifice*, which is of great importance in classification.

The last stage or pupal case is usually more elevated, somewhat segmented, and often discloses the developing parts of the imago. The adults emerge from this case through a T-shaped slit on the dorsum. There are from two to many overlapping broods a year, and the winter is passed in the immature stages.

White flies have much the same feeding habits as other homopterous insects and the young produce quantities of honeydew which is of chief concern to the horticulturist. Few of the species are serious pests while the great majority are confined to native plants.

The commonest and most widely distributed species is the **greenhouse white fly**, *Trialeurodes vaporariorum* (Westwood), which is a general feeder and has now become through commerce a cosmopolitan species. Protection in greenhouses has enabled it to live in many areas where it could not possibly exist out of doors. The smooth, semitransparent nymphs are characterized by the conspicuous wax rods which are secreted from the dorsum and margins of the bodies.

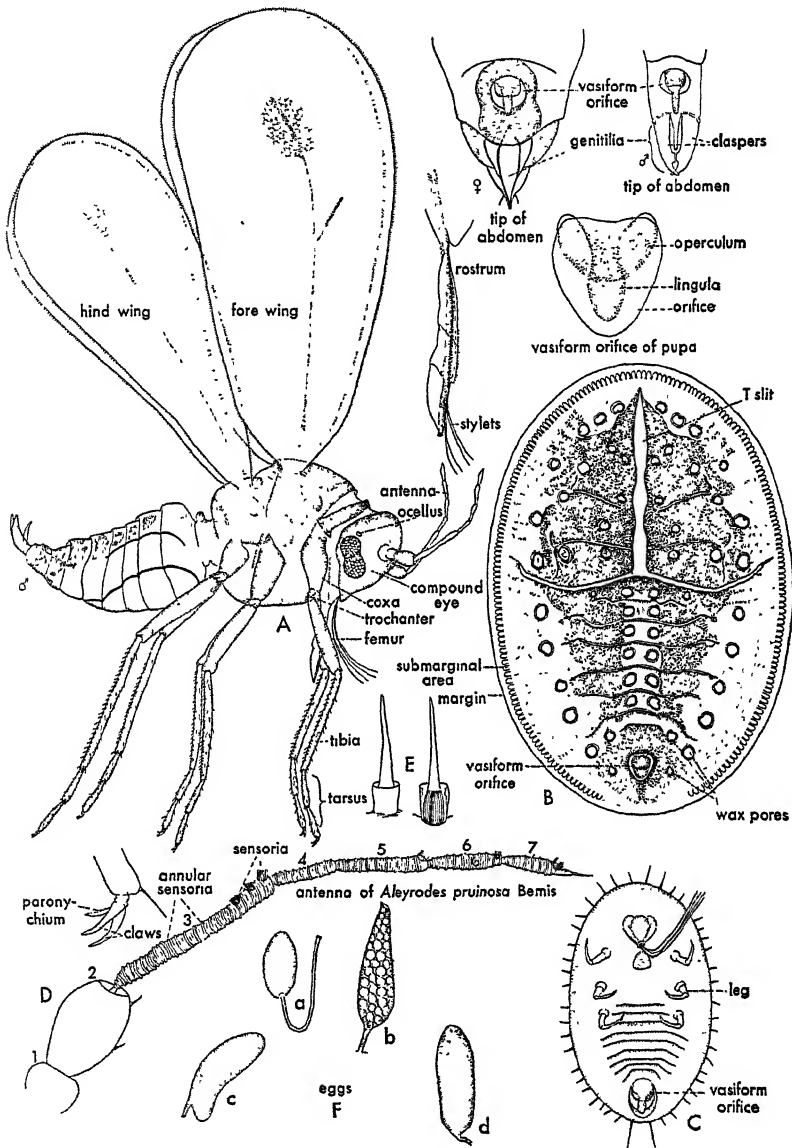


FIG. 110. ALEURODIDÆ. A, adult and D, antenna of the whitefly, *Aleurodes pruinosa* Bemis; B, nymphal exuvia and C, young of *Aleuroparadoxus iridescent* (Bemis); E, compound wax pores and F, eggs of *Aleurodicus holmesii* (Maskell); b, egg of *Aleurochiton forbesii* (Ashmead); c, egg of *Aleurocanthus woghumi* Ashby; d, egg of *Dialeurodes citri* (Riley and Howard). (B, C, E, F, after Quaintance and Baker, 1913.)

The citrus white fly, *Dialeurodes citri* (Riley and Howard), a species similar in general appearance to the above, except for the absence of nymphal wax rods in the latter, originated in southern Asia and has been distributed by means of nursery stock into Japan, Florida, and California.

This is quite a large family whose many species occur in both the temperate and tropical regions of the world on a great variety of plants. The most important genera are *Aleuroplatus* Quaintance and Baker, *Aleurodicus* Douglas, *Aleyrodes* Latr., *Asterochiton* Maskell, *Dialeurodes* Cockerell, and *Tetraleurodes* Ckll.

These insects may be preserved and mounted as recommended for scale insects.

V. Superfamily APHIDOIDEA¹ (Latreille 1802) Handlirsch 1903

This superfamily embraces all of the insects which in early days were placed in the common family APHIDIDÆ. In more recent times several groups have been separated off into distinct families until there are now the four distinct families that are briefly treated in the following pages.

Family ADELGIDÆ² Mordvilko 1935 (A-del'gi-dæ, from the Greek ἀδελος, concealed, + γῆ, in the earth; from the fact that certain closely related forms live upon the roots of plants). German, Tannenläuse. Adelgids.

Minute or very small apterous and winged insects with soft, fragile, oval, indistinctly segmented bodies, often entirely covered with threads and masses of white cotton-like wax which may hide them. Head and prothorax with dorsal chitinated shield. Wax pore areas or plates arranged in two transverse rows on head and prothorax and in one transverse row on the meso- and metathorax and abdomen; sometimes also a longitudinal ventral row is present, and plates frequently occur also on the coxæ; more apparent in the winter forms. Head with three ocellanæ on each side. Antennæ greatly reduced in winter forms; three-segmented in summer forms; sensoria in group at tip of, and one or two on sides of, apical segment. Legs differ somewhat in the various stadia. Tarsi two-segmented; basal segment small, apical segment with one or two digitules. Females with ovipositor. Spiracles, one pair each on the meso- and metathorax, and on each of abdominal segments II to V in *Pineus* and II to VI in *Adelges*; may be absent in first-instar larvæ. Winged forms with compound eyes and three ocelli; five-segmented antennæ (last three segments rarely fused together) and with three to five sensoria; wings with reduced venation as illustrated.

¹ The first conception of this group of insects as a unity appears to be that of Latreille 1802, who designated them as APHIDII. Other designations have been APHIDIÆ Fallén 1814, APHIDA Leach 1815, APHIDÆ Samouelle 1819, APHIDIDÆ Passerini 1862, and many others to date. Handlirsch established the superfamily APHIDOIDEA in 1903. See also the footnote under APHIDIDÆ, p. 331.

² The members of this small family were long known as the CHERMIDÆ Koch 1857 (CHERMIDEN) and CHERMESIDÆ Passerini 1862, 1867. The transference of the name *Chermes* to replace *Psylla* (see footnote 2, p. 320) has made it necessary to adopt the name ADELGIDÆ from the genus *Adelges* Vallot for this family.

These insects live on the twigs, needles, or in galls on coniferous trees. They have complex life histories, consisting rarely of a single host, or alternate hosts, comprising a primary host which is frequently spruce and an intermediate host such as pine, larch, fir, hemlock, or Douglas fir. Galls are generally pro-

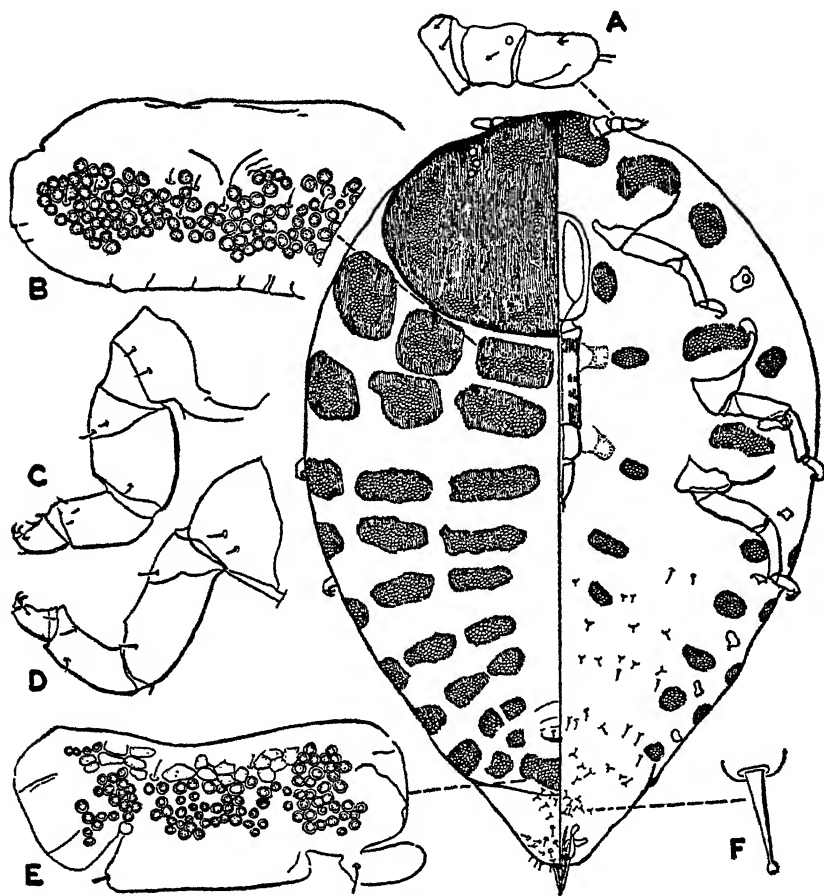


FIG. 111. *Adelges tsugae* Annand. Fundatrix. A, antenna; B, dorsal plate showing wax pores; C, hind leg of 3rd instar nymph; D, hind leg of adult; E, post anal plate; F, knobbed ventral seta. (After Annand, 1924.)

duced upon the primary host only. The forms involved in the polymorphic type are summarized as follows:

1. **Fundatrices** — apterous, parthenogenetic females which hatch in summer from the eggs laid by the sexual females on the primary host. They remain immature throughout the following winter and in the spring lay many eggs which give rise to the gallicolæ.

2. *Gallicolæ* — winged, parthenogenetic females arising from the eggs of the fundatrices on the primary host. They settle at the bases of the needles, where they produce remarkable cone-like galls. When wings are acquired in the fifth stadium, they fly to the intermediate hosts (excepting the species that remain on a single host) and lay eggs which hatch into the exsules.
3. *Virginogeniæ* or *exsules* — apterous, parthenogenetic females arising from the *gallicolæ* on the intermediate hosts. They consist of
 - (1) Stem mothers or *sistentes* (*Adelges*).
 - (2) *Neosistens* — first-stage larvæ which hibernate and reach maturity in the spring. In early spring, they lay eggs which hatch into *sexupara* and cycles of
 - A. *Progrediens* (*progreddients*) — apteræ with many wax glands which give rise to many generations alternating with *sistens*.
 - B. *Sistens* (*sistentes*) — apteræ having few wax glands which have a resting period. Two types are
 - a. *Hiemosistens*, which hibernate.
 - b. *Æstivosistens*, which æstivate.
4. *Sexuparæ* — winged, parthenogenetic females resembling the *gallicolæ* and arising from eggs of *sistentes* on intermediate hosts. They migrate back to the primary host and produce the *sexuales*.
5. *Sexuales* — minute, apterous, sexual males and females with long slender four-segmented antennæ. *Sexuales* arise from the eggs of the *sexupara* on the primary host. After mating, the female lays a single egg.

The members of this small family are chiefly found in the coniferous forests and ornamental plantings of the north temperate zone and have been carefully studied in Europe and North America where most of the known species occur. A number of species have been introduced into other regions, and certain species are now of economic importance in Australia and New Zealand. The following genera are known at the present time: *Adelges* Vallot, *Aphrastasia* Börner, *Cholodkovskya* Börner, *Dreyfusia* Börner, *Gilletteella* Börner (= *Gillettea* Börner), *Pineodes* Börner, *Pineus* Shimer, and *Succhiphantes* Curtis (= *Chermes* Linn.). Annand (1928) lists 20 species in North America, seven of which also occur in Europe.

A few representatives may be mentioned as follows: *Pineus lævis* Maskell (= *börneri* Annand) has been widely distributed in New Zealand, South Africa, Formosa, Korea, Europe, and California where it infests many species of *Pinus*. *Pineus strobus* (Hartig) infests white pine, and *P. cembra* Cholod. lives on Swiss stone pine in Europe and North America. *P. coloradensis* Gillette lives on a wide variety of pine trees in western North America. *Pineodes pinifoliæ* (Fitch) produces large terminal galls mostly on young spruce and also on pine trees, and overwinters on pines in North America. *Dreyfusia nordmannianæ* Eckstein (= *nüsslini* Börner) is common to Europe and North America and alternates from spruce to fir and *Pseudotsuga*. *D. picea* (Ratze-

burg) alternates from spruce to fir in North America and Europe. *Gilletteella cooleyi* (Gillette) produces terminal galls on spruce and alternates to *Pseudotsuga*.

Specimens are preserved and mounted for study as outlined for aphids. Staining is an important step in making slides for microscopical studies.

Family PHYLLOXERIDÆ (Koch 1857) Dreyfus 1889 (Phyl'lox-er'i-dæ, from the Greek φύλλον, a leaf, + ξηρός, dry, withered; in reference to the attacks of the insects, causing the leaves of the vines to dry up). German, Zwergläuse. French, Phylloxerides. Phylloxeras.

Minute insects closely related to the aphids and adelgids with oval soft bodies which are naked or covered with cotton-like wax; without cornicles.

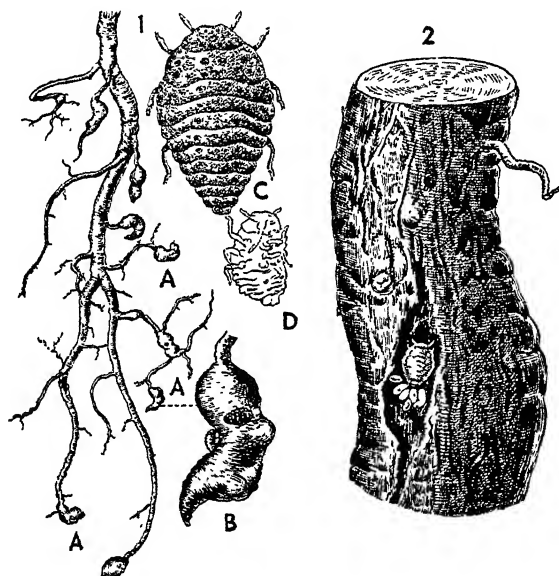


FIG. 112. The grape phylloxera, *Dactylophara vitifoliae* Shimer. 1, adult female and nodosities formed on the roots of grape; A and B, nodosities and 1st instar phylloxeras; C, adult female; D, cast exuvia; 2, section of root showing adult female and eggs. (After Davidson and Nougaret, 1921.)

The color is various shades of yellow, orange, or red. The antennæ are three-segmented, and the wing venation is similar to that of the adelgids. The biology is quite complicated, and some species may have many forms in the life cycle. All reproductives are parthenogenetic or oviparous. Little is known concerning the biology of the many forms that occur in nature.

The most noted member of the family, and one of the most important of all economic insects, the **grape phylloxera**, *Dactylophara vitifoliae* Shimer,¹ has

¹ This species was originally described by Fitch as *Pemphigus vitifoliae* in 1854 and has for many years been placed in the genus *Phylloxera*. In 1930, Börner (*Archiv. Klassifik. phyllo-*

been carefully studied since it was discovered in the vineyards of France in 1868 and became a very serious pest by 1875, yet there is no common agreement among entomologists in Europe as to the finer points in its life history. It is a very small species, varying from 0.3–1.2 mm. in length and yellow or greenish-brown in color. Apterous forms occur upon the roots of the grape throughout the year and constitute the only ones to be found in many regions and particularly upon European vines. A tabulation of forms follows:

1. *Fundatrices* or *gallicolæ* — arise from the overwintering eggs laid on the trunks and branches of the vines. Apteræ which produce galls on the foliage of American vines and rarely on European vines lay many eggs which hatch into fundatrigeniæ. Rarely met with except on American species of *Vitis*.
2. *Fundatrigeniæ* — apterous, parthenogenetic females arising from the *gallicolæ*. Dimorphic and giving rise to
 - (1) *Gallicolæ* — which make galls upon the foliage in early summer. In Germany Börner and Schilder in 1938 noted a form with a short rostrum and a more numerous form with a long rostrum — the latter does not infest the leaves.
 - (2) *Radicolæ* — which live on the roots and are abundant in late summer. May hibernate as nymphs. May produce small swellings or nodosities on the little roots. They produce sexuparæ.
3. *Sexuparæ* or *migrants* — winged, parthenogenetic females arising from the fundatrigeniæ. Migrate to other vines and oviposit on the branches, giving rise to the sexuales. Eggs of two kinds, large ones which produce sexual females, and small ones which hatch into males.
4. *Sexuales* — minute, apterous males and females on the branches. After mating, each female lays a single egg on the trunks or branches. Eggs overwinter and hatch into fundatrices in the spring.

In vineyards where only the European vine, *Vitis vinifera* Linn., is grown the winged forms are apparently sterile, and dissemination is by crawlers or wanderers which crawl from vine to vine. This species, while very destructive to European vines, does little damage to the native American grapes upon which it generally subsists. Control was effected by grafting the European varieties upon the most resistant types of American varieties. This saved the viticulture of Europe but has had little to do with the extensive culture of European grapes in California. The species has been distributed widely through commerce and now occurs practically everywhere grapes are grown.

Very little systematic work has been done in this family in America for many years. Many species are known to occur in the hardwood forests east of the Rocky Mountains and there are a few which occur on poplars and willows throughout the country. The work of Börner (1932) on world species lists the

genetische Ent. 1:159) relegated it to the genus *Dactylosphæra* Shimer 1867 (*Daktulosphaira*) and listed the following synonyms: *Viteus* Shimer 1867, *Rhizaphis* Planchon 1867, *Peritymbia* Westwood 1869, *Rhizocera* Kirkaldy 1897, *Xerompelus* del Guercio 1900, *Börneria* Grassi and Foà 1908, *Foiella* Börner 1909.

following genera and species: *Phylloxera* Börner, three species; *Guercioja* Mordvilko, three species; *Acanthohermes* Kollar, one species; *Aphanostigma* Börner, two species; *Dactylosphæra* Shimer (= *Peritymbia* Westwood), two species; *Phylloxera* B. de Fonscolombe, 10 species; *Moritzella* Börner, seven species; *Xerophylla* Walsh, 25 species; *Parapergandea* Börner, one species; *Troitzkya* Börner, one species.

Specimens are preserved and mounted as recommended for aphids and adelgids. Staining is important for microscopical examinations.

Family ERIOSOMATIDÆ (Baker 1920) Börner 1930 (= PEMPHIGIDÆ Weber 1933) (Er'i-o-so-mat'i-dæ, from the Greek *ἔριον*, wool, + *σῶμα*, σῶμαρος, body; referring to the white waxy covering). Woolly and Gall-making Aphids.

This family comprises specialized forms which are characterized by a simplification in the structure of the wings involving a reduction of veins; a complete absence of or a reduction in the cornicles from mere rings to very short cone-like organs; and a modification in the sexes which are very small, apterous, and have the mouth parts atrophied so that they are unable to feed. Most species have special wax-secreting organs which are very large, especially in the apterous forms, but which are also well developed in the alates.

Many species produce galls, pseudogalls, leaf rolls, excrescences, and other malformations on the woody primary hosts but cause no such excessive growths on the secondary hosts. The alternation of host plants is a characteristic which involves many intricacies not yet wholly solved. The primary hosts are chiefly trees and woody shrubs whereas the secondary hosts are grasses and more or less succulent annuals and perennials. The roots of certain primary as well as those of most secondary hosts are attacked. In parts of California the **pear root aphid**, *Eriosoma lanuginosum* (Hartig), may continue indefinitely upon the roots of pear trees while *Pemphigus populi-transversus* Riley may live on the roots of sugar beets, dock, and lettuce over a period of years if the land is successively cropped and volunteer plants allowed to support the overwintering populations. It occurs at least in North America and in Australia and New Zealand (Tillyard).

The most important cosmopolitan species is the **woolly apple aphid** or **American blight**, *Eriosoma lanigerum* (Hausmann), a red species that envelops the bodies in a mass of fluffy white cottony or woolly waxy secretion which makes it conspicuous on the branches of the host plants. This species attacks both the roots and the tops of the trees, being primarily a bark feeder, and in so doing causes large and small excrescences on the bark which afford an abundance of newly formed bark for food and places of protection. In the cooler limits of its distribution, apterous sexual forms appear and eggs are produced, while in the more temperate areas these stages are omitted. Winged migrants which appear in the late summer and fall may disperse and establish new colonies on other hosts. The alternation from *Pyrus* to *Ulmus*, reported elsewhere, is as yet not observed in California, but the closely related *Eriosoma lanugino-*

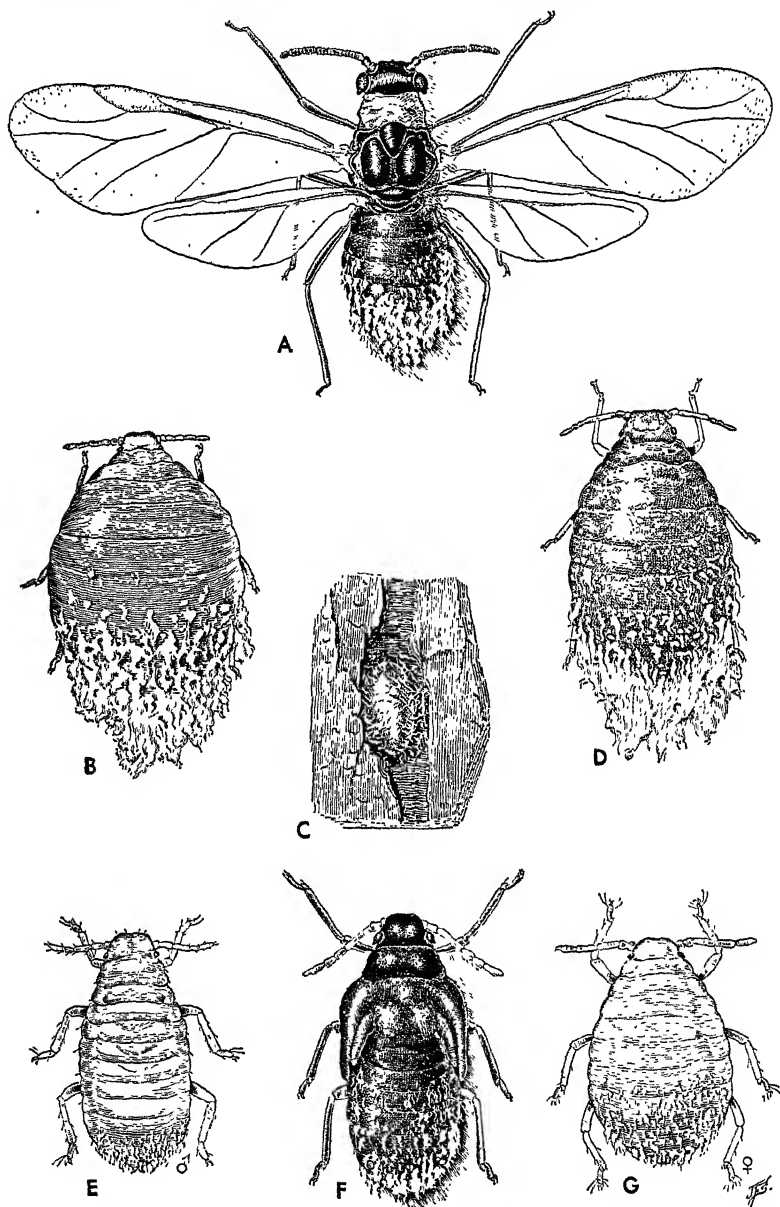


FIG. 113. The woolly apple aphid, *Eriosoma lanigerum* (Hausmann). A, winged ovoviparous female (sexupara); B, stem-mother (fundatrix); C, egg; D, wingless female (alienicola); E, male (sexual); F, nymph of fall migrant; G, oviparous female (sexual). (After Baker, U.S.D.A., 1915.)

sum (Hartig) has been observed to form large pseudogalls on the leaves of elms in a few instances. The latter, however, may subsist entirely upon the roots of pears.

Members of the subfamily FORDINÆ have complicated life histories involving primary and secondary hosts. Galls are made on the leaves of the former, and the roots of the latter are the source of food. *Paracletus pallidus* Derbès, *Forda follicularia* Passerini, and a number of other species of *Forda* Heyden as well as those of *Tetrenema* Derbès produce curious galls on *Pistacia* and alternate to the roots of grasses in parts of Europe and Asia where the primary host is available. *Trifidaphis phaseoli* Passerini is a widely distributed Holarctic species living upon the roots of many plants.

The galls of the Asiatic *Melaphis chinensis* (Bell) produced on *Rhus semialata* have long been used by the orientals as a source of dye, tannin, and for medicinal purposes.

A large number of species in several genera produce galls on species of *Populus* as the primary hosts and alternate to the roots of a large number of other plants such as beets, dock, lettuce, dandelion, chickory, and cabbage. These genera include *Pemphigus* Hartig, *Mordwilkoja* Del Guercio, *Prociphilus* Koch, and *Thecabius* Koch.

Family APHIDIDÆ¹ (Buckton 1881) (as APHIDINÆ) (A-phid'i-dæ, possibly from Greek ἀφίω, to draw liquids; referring to the sap-feeding habits of these insects. German, Aphiden. French, Les pucerons. Aphids, Aphides, Plant Lice, Green Flies.

A large family of minute to small, elongate and robust, soft-bodied, fragile, phytophagous insects; apterous or winged; naked or pruinose or more or less covered with white waxy secretions; active, rarely stationary; with parthenogenetic and sexual forms; feeding wholly upon the juices of living plants; with small stomach and simple or primitive filter chamber and without Malpighian tubules; excreting honeydew.² Head small, closely fitted to prothorax, and widest at base. Antennæ variable but usually setiform, three- to six-segmented, the last segment often with base and more slender filament or unguis, with transverse band-like, elongate, or circular sense organs or sensoria. Eyes com-

¹ The etymology of the family name has long been the object of misunderstanding and disagreement which arises from the fact that Linnæus never explained the origin of the word *Aphis*. Buckton (1876) has discussed at length the etymology of it but arrived at no definite conclusions. John Varres, a Greek scholar at the University of California who has greatly assisted me in the etymology of entomological names, has, independently of the remarks by Buckton, suggested the Greek adjective ἀφειδής, meaning unsparing, lavish, and no doubt referring to the prolificness of these insects. The Greek genitive of this word is ἀφειδούς. The French entomologist C. J. B. Amyot thought the name was derived from the Greek verb ἀφίω, to draw liquids, which seems quite fitting. In either case the English form of the root would be *aphid*. Therefore, the correct form of the family name is APHIDIDÆ and not APHIDÆ. In discussing this matter with Frederick Laing of the British Museum I was informed that one of the leading Greek scholars in England had arrived at the same conclusions.

² According to Wigglesworth (1939) aphid honeydew is composed of 16.7 per cent sucrose, 24.5 per cent invert sugar, 39.4 per cent dextrin, and 3.0 per cent protein.

posed of groups of three or more ocelli or large, hemispherical, and faceted; and without or with a posterior terete tubercle. Ocelli, three, present in the winged forms only (but present also in some apterous males). Rostrum well developed, short or longer than the body, three- to four-segmented; setæ or piercing lancets very long. Thorax well developed and distinct in alates or winged forms and more or less fused with the abdomen in the apterous forms; pronotum

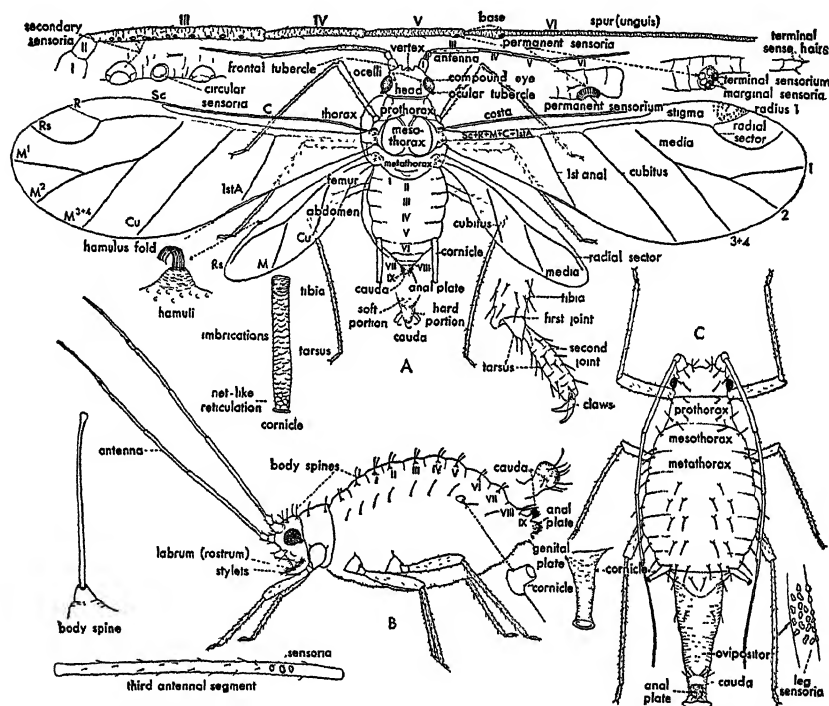


FIG. 114. Characters of APHIDIDÆ or plant lice. A, winged migrant of *Macrosiphum scoti* Essig; B, sexual female of the bamboo aphid, *Myzocallis arundinaria* Essig; C, sexual female of the maple aphid, *Drepanosiphum acerifolii* (Thomas).

usually distinguishable and in alates may have a pair of lateral tubercles; pro- and metathoracic spiracles. Wings present on migrants and certain sexuales, usually males; normally as long as or longer than body; thin and transparent or partly clouded; few-veined; hind pair much smaller, with fewer veins, and bearing hamuli; folded roof-like or rarely flat over the back. Legs short or long and rather slender; often hairy; tibiae of sexual females often swollen and with numerous sensoria-like areas; tarsi usually two-segmented with basal segment small, rarely one-segmented or absent; claws, one pair, simple, without arolia. Abdomen indistinctly segmented and with eight or nine segments at most; wax glands, lateral and dorsal tubercles, and hairs or setæ usually present.

Cornicles or oil- or wax-secreting organs absent or present; variable in size and shape from mere rings to long, cylindrical or swollen, straight or curved tubular organs almost as long as the body; smooth, imbricated, partly reticulated, or hairy, with or without flaring opening. Seven pairs of spiracles; with cauda or tail, anal plate, genital plate, and rarely with precaudal tubercle (in *Cavariella*). Male genital organs consist of a pair of valves, penis, and genital plate.

The biologies of aphids present to the student some complex problems owing to the number of kinds of forms, reproduction by parthenogenesis and sexuales, alternation of host plants, and variations in the life histories because of climatic factors.

Kinds of forms

1. **Fundatrices or stem mothers** — apterous or winged, viviparous,¹ parthenogenetic² females. From overwintering eggs on the primary host.
2. **Fundatrigeniæ** — apterous or winged, viviparous, parthenogenetic females. Several generations from the fundatrices. This form may be omitted in some species of the subtribes CALLIPTERINA and DREPANOSIPHINA in which only certain of the sexual forms are truly apterous as in *Callipterus*, *Myzocallis*, *Drepanaphis*, *Drepanosiphum*, and others.
3. **Migrantes or migrants** — winged, viviparous, parthenogenetic females arising from the second or third generations of the apterous fundatrigeniæ on the primary host. They disperse or migrate either to other similar hosts, where they give birth to apterous and winged individuals, or to secondary hosts, where they usually produce only apterous forms.
4. **Alienicolæ or seconds** — apterous, viviparous, parthenogenetic females born on the secondary hosts and comprising several to many generations. They appear much the same as the fundatrigeniæ.
5. **Sexuparæ or gynoparæ** — apterous or winged, viviparous, parthenogenetic females, offspring of the alienicolæ, which give birth to winged sexuales, either on the secondary host or after migrating back to the primary hosts.
6. **Sexuales or sexes** — male and female progeny of the sexuparæ, either born on the secondary host, whence they migrate to the primary host, or born on the primary host. Females usually apterous; males apterous or winged or both forms may occur within the species. They feed very little or not at all, develop rapidly, and mate. The females lay from one to several or many eggs, usually around the buds or on

¹ These forms are also often referred to as being ovoviviparous because the egg hatches within the body.

² Reproducing without mating.

the twigs of the current year's growth. The adults normally perish before winter.

The forms discussed above represent normal development in the cooler temperate regions of species having alternate host plants. There are, however, many common species like the green peach aphid, *Myzus persicae* (Sulzer), the geum or potato aphid, *Macrosiphum euphorbiae* (Thos.), and the cotton aphid, *Aphis gossypii* Glover, which are omnivorous feeders and do not normally require specific hosts to ensure development but disperse or wander from plant to plant within the range of the winged or crawling migrants. Even in the case of the mealy plum aphid, which requires alternate hosts, the apterous forms may crawl from one primary host to another and give rise to new colonies throughout the entire summer along the mild coastal areas of middle California. Then, too, species which require alternate hosts and others which produce sexuales and overwintering eggs in the cooler limits of their distribution may alter their requirements when inhabiting warmer or milder regions. Thus in parts of California such common species as the green apple aphid, *Aphis pomi* DeGeer and the rosy apple aphid, *A. malifoliae* Fitch, may reproduce parthenogenetically throughout the entire year by maintaining colonies on evergreen hosts (*Coloneaster*, *Pyracantha*, *Crataegus*, etc.) during the winter months. The rose aphid, *Macrosiphum rosae* (Linn.), the cabbage aphid, *Brevicoryne brassicae* (Linn.), and innumerable other species apparently never produce sexuales or eggs at all in subtropical and tropical areas. The mealy plum aphid and other species with complicated life requirements in the north temperate regions have quite simple habits in the tropics where they may reproduce parthenogenetically throughout the year on a single host.

The eggs are very small, regularly oval or with a constriction at one end (*Myzocallis arundinariae* Essig). They are pale yellow or green when first laid but soon turn shiny black. Certain species cover the eggs with waxy threads [*Plocomaphis flocculosa* (Weed)] or with transparent waxy rods [*Hyalopterus arundinis* (Fab.)], but these accessories soon weather away, leaving the eggs unprotected save for their location near a bud or in a crack of the bark. They hatch as the buds begin to swell or open in the spring, and the young feed upon the developing leaves. Maturity is reached in a very short time, from 2 to 3 weeks, and embryos may be developing in the nymphs even before the last molt.

A discussion of all the various forms of aphids is impossible here, and a synopsis of important characters only is included:

I. Females

1. **Apteræ or wingless parthenogenetic individuals** — the commonest members throughout most of the year. Body more or less undifferentiated but with distinct head, large eyes, and antennæ usually only with primary sensoria; a few with secondary. Usually unicolored — green, yellow, reddish or maroon, brown, olive, black, and mottled; sometimes with black pigmentations. Often red and green individuals in

the same species. Pulverulent, or with white wax tufts, or shining, smooth, hairy, or tuberculate. Usually active throughout life, but some species become scale-like or aleyrodiform and are fixed after the first molt. Active forms may drop when disturbed and feign death for some time.

2. **Winged parthenogenetic individuals** — usually migrants, which serve to distribute the species. Normally darker than the apteræ and particularly with black portions on the head and thorax and appendages and dark markings on the abdomen. Antennæ may have many secondary sensoria. Usually active and may jump and fly readily if temperature is sufficient.
3. **Sexual Females** — usually apterous individuals normal in size or extremely small. Abdomen often drawn out posteriorly into a long tapering tube. Hind tibiae normally swollen and with few or many sensoria-like areas. Antennæ with primary sensoria. Rather inactive. Often darker than parthenogenetic females. Most abundant in the fall.
4. **Males** — apterous or winged but in either case much the same. Minute to very small. Often much darker in color than other members of colony. Active, with very many sensoria on antennal segments III to VI. Genital plate conspicuous. Penis often extended downwards. Most abundant in fall.

As many as 10 or 13 generations may be produced within a year. Populations which have not been reduced by the many natural means (fungi, bacteria, parasites, predators, heat, cold, and other climatic factors) may become enormous and may very seriously injure or completely destroy agricultural crops. A number of species, chief of which is *Myzus persicae* (Sulzer), carry serious plant diseases which make them even more formidable as economic pests.

As a group they feed upon a wide variety of plants and infest the leaves, stems, living bark, fruits, and roots. They cause deformations on the roots and branches, oddly shaped galls on the stems and foliage, and pseudogalls on the leaves. They excrete quantities of honeydew which is deposited as very fine droplets over the plants and objects beneath. This sweet, sticky substance may collect in considerable quantities and become quite annoying. It is sought by ants, bees, flies, and many other insects. Ants are noted for their attendance upon aphids, which they protect, transfer to some extent from host to host, and stroke with their antennæ for the honeydew. A black smut fungus also grows on the secretion which makes the presence of aphids the more objectionable in gardens, parks, and on street trees. About the only good thing that can be said for aphids is that they are an important article of diet of many small attractive birds such as the chickadees, warblers, sparrows, and flycatchers, and of many ladybird beetles, syrphid flies, wasps, and parasites.

Collecting. — Aphids may be collected and preserved in 70 per cent alcohol for an indefinite time by submerging cotton-plugged vials in a tight jar of the preserving fluid. From time to time the jars may be replenished if necessary.

Mounting. — Aphids should be thoroughly cleared and the nonpigmented forms stained for study. This necessitates a considerable technique and skill. The old method of mounting directly into balsam or euparal renders the specimens almost useless for microscopic examination.

Temporary mounts. — Very good temporary mounts for immediate study may be made by mounting living or fresh specimens directly into the so-called Faure, Berlese, or chloral hydrate-gum arabic mixtures. After arranging the specimens and completing the mount the slides should be placed in a warming oven at 120°F for 1 hour to permit clearing, inflation, and to seal the cover glass. Subsequent ringing with a suitable cement like "Murryite" may prolong the life of the slides. In case of crystallization or deterioration the specimens may be removed and remounted.

Permanent mounts may be made according to several methods, of which two are recommended:

1. **Caustic Potash.** — Fresh specimens or those preserved in alcohol or formalin or dried are immersed directly in a 10 per cent solution of KOH (or NaOH) and placed in a warming oven, boiled over a flame, or set aside in closed containers and will soon become relaxed and cleared. Embryos should be removed even though cleared if the specimens are to be stained. Transfer to full-strength acetic acid, tease or press out KOH solutions, and remove to fresh acetic acid for 10 minutes. They may be stained in this solution by adding acid fuchsin or alcoholic fast green or other stain. Remove to clove oil for 5 minutes. Transfer directly into canada balsam from one to five or six specimens, including various forms stained or unstained. Place cover glass.
2. **Lactic Acid.** — Fresh specimens or those preserved in alcohol or other preservative are removed to a solution composed of lactic acid 50 parts, 95 per cent alcohol 35 parts, and water 15 parts. Set in a closed dish in a warming oven at 120°F for 24 hours for fresh specimens to 48 hours for preserved ones. Tease out embryos. Stain if necessary. Transfer to acetic acid, then to clove oil, and mount in balsam; or transfer to 95 per cent and absolute alcohol, then to clove oil, and mount either in balsam or euparal.

Many fossil remains of aphids have been found despite the small size and delicate structure of these insects. The oldest known fossil is *Canadaphis carpenteri* Essig (1937) taken in Cretaceous Canadian Amber. It has the aphid-type wings showing the greatest development in venation, six-segmented antennæ with apical filament or spur, tuberculate eyes, and two-segmented tarsi with a pair of claws. Numbers of specimens have been taken in Oligocene Baltic Amber and in the shales of Florissant, Colo.

The family is widely distributed in the temperate regions of the world¹

¹ There is but a single indigenous species, *Anomalaphis comperei* Pergande on *Acacia* and *Eucalyptus* in Australia and none in New Zealand. The original description of *Aphis coprosmae*

and reaches the greatest development in the north temperate zone. The members are singularly scarce in the tropics although many species have been described from southern Asia, particularly from Formosa and Java. There yet remains much to be done in collecting and studying them in other equatorial regions.

The family is composed of a considerable number of subfamilies, tribes, and subtribes, and no less than 150 genera and nearly 2,000 species. Lack of space prevents the inclusion of more than a few representative species.

Members of the genus *Cinara* Curtis are large brownish or greenish hairy species which generally feed upon coniferous trees. The important species occurring in both Europe and North America are *C. pinicola* (Kalt.) on *Pinus* and *Larix*; *C. piceæ* (Walker) (= *vanduzeei* Swain) on *Picea* and *Abies*; *C. juniperi* (DeGeer) on *Juniperus*; and *C. tujaefilina* (Del Guercio) on *Thuja*, *Cupressus*, and *Retinispora*.

Lachniella costata (Zetterstedt) is smaller but otherwise similar to species of *Cinara*. It is common in Europe on *Pinus*, *Picea*, and *Abies*.

The large willow aphid, *Pterochlorus salignus* (Gmelin), is one of the largest species, attaining a length of 5 mm. It is brown with a large, conspicuous triangular tubercle on the middle dorsum just in front of the short cornicles. It is common on willow, rare on poplars, and occasionally on apple, apricot, and peach and occurs throughout parts of Europe, Africa, Asia, and North America.

Stomaphis quercus (Linn.), infesting oaks, maples, poplars, and willows in Europe, is remarkable for the very long rostrum which may be nearly twice the length of the body.

Euceraphis betulæ (Linn.) and *Calaphis betulæcolens* (Kalt.) occur on birch in Europe and North America. *Phyllaphis fagi* (Linn.) is a white woolly species on beech with the same wide range.

Drepanosiphum platanoides (Schrank), a large green species, is common on maple in Europe and North America. It is very active on bright, hot days.

Species of the genus *Myzocallis* Passerini are mostly small and yellow with or without clouded wings and dorsal abdominal tubercles. *M. ononidis* (Kalt.) (= *trifolii* Monell) occurs on *Ononis* and *Trifolium* in Europe, northern Asia, and North America. *M. tiliaæ* (Linn.) occurs on linden wherever grown in Europe, Asia, and North America. *M. coryli* (Goeze) infests *Corylus*, *Carpinus*, *Quercus* and *Primula* in Europe and *Corylus* in North America. *M. castanicola* Baker feeds on *Carya*, *Castanea*, *Quercus*, and related plants in Europe, Asia, North America, and New Zealand.

Three common species of *Periphyllus* Van der Hoven: *P. aceris* (Linn.), *P. negundinis* (Thomas), and *P. testudinatus* (Thornton) are dark-green or blackish species infesting maples. They occur in Europe and North America, excepting *P. negundinis* (Thomas) which occurs only in North America.

Laing, reported by Tillyard from New Zealand, was never published unless the description by the latter is sufficient to establish the species. Many species have been introduced into both areas through commerce.

The two species *Pterocomma populea* (Kalt.), infesting the stems of poplars, and *P. salicis* (Linn.), on willows, are common to Europe and North America. They are large brown aphids with short bright-orange cornicles. Their honeydew is often an abundant source of honey for the common honeybee.

The genus *Aphis* Linn. is a very large one and has been divided into a number of genera during the past few years. Some of these names are *Brachy-*

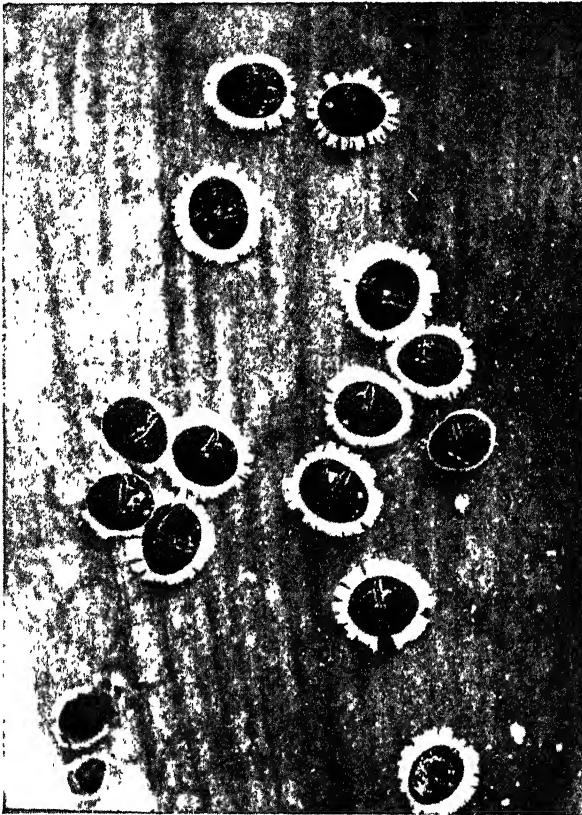


FIG. 115. The latania aphid, *Ceralaphis lataniae* (Boisduval), a tropical American species common on orchids, Bourbon palm, sweet flag, and other plants grown in greenhouses. Apterous alate females. (From *Insects of Western North America*.)

caudus v.d. Goot, *Appelia* Börner, *Yezabura* Matsumura, *Doralis* Leach, and *Anuraphis* Del Guercio. They are not employed here because their validity is still uncertain. Some of the very common species occurring in Europe, North America, and other parts of the world are: *Aphis sambuci* (Linn.) (= *sambucifoliae* Fitch), a dark species on elderberry; *A. medicaginis* Koch, a shiny black aphid on legumes and other plants; *A. grossulariae* Kalt., curling

the terminal leaves of gooseberry; *A. gossypii* Glover (= *symphiti* Schrank? *frangulæ* Koch?), a small variable species, infesting a large number of hosts and particularly injurious to cucurbs, cotton, citrus, solanums, and legumes, which transmits cucumber mosaic; *A. pomi* DeGeer, a small green cosmopolitan species on *Prunus*, *Pyrus*, *Crataegus*, *Cotoneaster*, *Pyracantha*, *Sorbus*, and related plants; *A. maidis* Fitch, a dark-green pest of corn and sorghums in North America, Hawaii, South Africa, and Japan. The short cornicled forms referable to *Brachycaudus* and *Anuraphis*, which are now almost cosmopolitan, are *Aphis helichrysi* Kalt. on *Prunus*, *Compositæ*, and *Boraginacæ*; and *A. persicæ-niger* Smith, a shining dark-red and black species infesting chiefly the stems and roots of peaches and Japanese hybrid plums in North America, southern Europe, South Africa, and Australia. In California the apterous, parthenogenetic females survive the winters on the small twigs of the hosts. The tulip aphid, *Aphis tulipæ* B. de Fonsc. (*Yezabura*), is a pruinose dull-green species living chiefly on the bulbs, root stalks, and flowering stems of lilies, tulips, gladiolus, crocus, and similar bulbs and irises in Europe, Asia Minor, North America, Bermuda, New Zealand, and other places where it has been carried by commerce.

The mealy plum aphid, *Hyalopectus arundinis* (Fab.), a green pruinose species often very abundant on the foliage of the primary hosts, plums, prunes, peach, and apricot, alternates to the secondary hosts, *Typha*, *Phragmites*, and *Arundo* in the temperate and tropical regions where these necessary hosts occur.

The water lily aphid, *Rhopalosiphum nymphææ* (Linn.), is a large dull-green or maroon species which is cosmopolitan in distribution and alternates from the primary hosts, almond, apricot, and plum, to a wide variety of water plants, *Nymphaea*, *Nuphar*, *Alisma*, *Butomus*, *Sagittaria*, *Polomagelon*, *Ranunculus*, *Typha*, *Lemna*, etc. It is to be found in almost every lily pond and in greenhouses.

The cabbage aphid, *Brevicoryne brassicæ* (Linn.) (*Aphis*), a robust, striped, pulverulent species, infests CRUCIFERÆ throughout the world. As many as 16 generations a year have been recorded by Herrick (1925).

The green peach aphid, *Myzus persicæ* (Sulzer) (*Myzodes*, *Phorodon*), is one of the most important cosmopolitan and omnivorous species because of the many plant diseases which it is known to disseminate. It is a pinkish or greenish species in which the alates have slightly swollen cornicles and a dark dorsal patch between and in front of the cornicles. The black cherry aphid, *M. cerasi* (Fab.), is also widely distributed on cherries.

In the genus *Macrosiphum* Passerini are many large green and reddish-brown species which feed upon a wide variety of plants. Four important cosmopolitan species are: the rose aphid, *M. rosæ* (Linn.), composed of green and pinkish individuals which infest the terminal shoots and buds of wild and cultivated roses; the potato aphid, *M. euphorbiæ* (Thomas) (= *gei* Koch, = *solanifolii* Ashmead), wholly green or pinkish, omnivorous and often very destructive; the pea aphid, *M. pisi* Kalt. [*Acyrtosiphon onobrychis* (B. de Fonsc.)], a large green aphid which is a serious pest of legumes; and *M. granarium* (Kirby), almost universally found on grasses and cereal crops.

VI. Superfamily COCCOIDEA¹ Handlirsch 1903

(Coc-coid/de-a, from the Greek κόκκος, a grain or seed; because some of the first known forms, such as the cochineal, were thought to be seeds rather than insects.) Scale Insects, Coccids, Mealybugs, Lac Insects, etc.

Minute to small and often inconspicuous insects which are among the most highly specialized of all HEMIPTERA and the most heterogenous of all insects. It was years before the early students of natural history recognized certain coccids as living animals, and it is recorded that a lawsuit was necessary in Amsterdam to decide that cochineal was an insect rather than a seed. In view of the great variation among the different families it is impossible to give more than the barest facts which might be representative of the whole group.

Though the adults of most species are minute to small, varying from 0.5–2 mm. in circumference or length, the females of the large Australian *Apiomorpha duplex* Schrader attain a length of 1½ in. and inhabit a ribbed, elongated gall on eucalyptus up to 3 in. in length (Tillyard, 1926) and the giant *Leptococcus maximus* Saunders of South Africa is somewhat circular and up to 1 in. in diameter.

The bodies that are naked are usually heavily chitinized exteriorly while the large majority of species, which are protected by wax, secreted in a great variety of consistencies, or are covered by a tough scale or shell, have, as a rule, a soft and delicate exoskeleton. The male has well-defined body regions, but the female appears as a poorly organized mass of inert living material. Although the members of many families are able to move more or less freely though slowly throughout life, others, when mature, are capable of very little or no movement. The first born, however, are all active and energetic. In fact, it is almost impossible to conceive how so much action and endurance can be incorporated into a living object so small and fragile. These wanderers keep on the move and can travel long distances in search of food over a period of several days. But after the first molt certain species, particularly in the family DIASPIDIDÆ, shed with the skin their antennæ, legs, and anal spines so characteristic of young coccids and become fixed for life, protected beneath and above by a waxy-chitinous shell and supplied with the juices extracted from the plant to which they are attached.

In general the females may be further characterized by having the body distinctly segmented or all of the segments fused together; eyes poorly developed and arranged in groups of simple lenses or ocellanæ; antennæ well developed and from one- to nine-segmented or atrophied; mouth parts with rostrum inconspicuous, one- to two-segmented and the stylets usually very long and coiled in the body; legs normal, atrophied, or absent (certain rare species retain only the fore or the hind pair); claws, one pair, simple or with denticle, with or without digitules; with two pairs of thoracic spiracles and without or with two, three, seven, or up to eight pairs on the abdomen; poste-

¹ Fallén 1814 established the group under the name COCCIDES. Leach 1815 also used this name, and Stephens 1819 applied the family name COCCIDÆ in the same all-inclusive way. This was generally accepted until Handlirsch 1903 established the superfamily COCCOIDEA and elevated certain of the subfamilies to family rank, a practice which still continues.

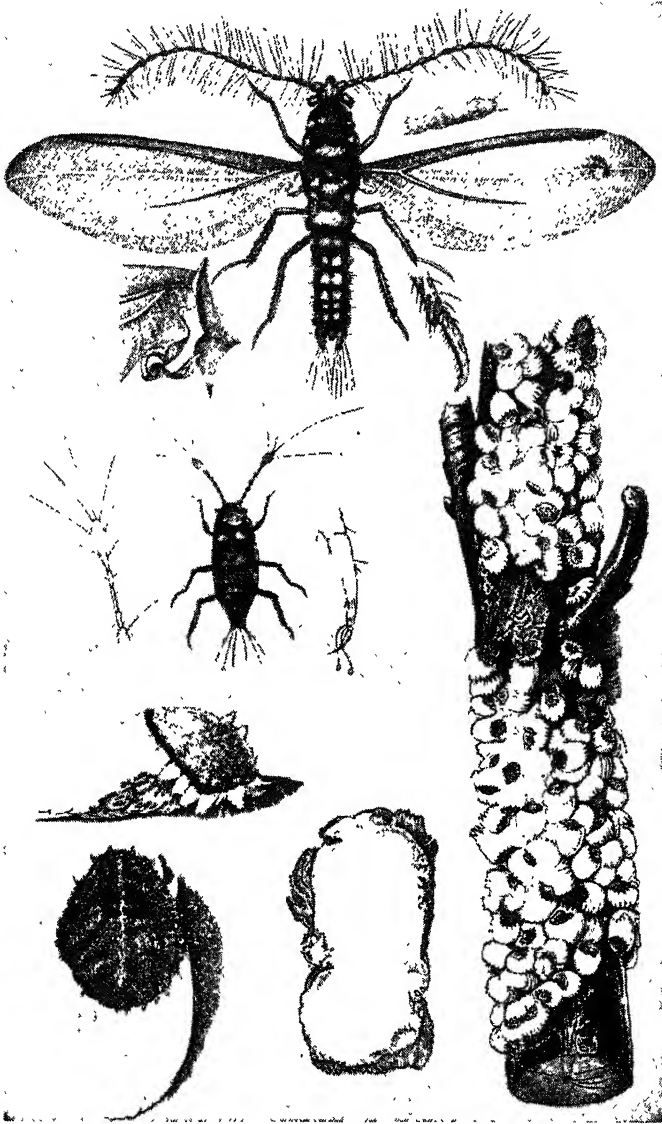


FIG. 116. The cottony cushion scale, *Icerya purchasi* Maskell. This excellent illustration by Riley, 1886, is one of the first to depict the life history of this important insect. (After Riley from *A History of Entomology*.)

rior end of abdomen with anal lobes, valves, ring, or pygidium and variable arrangements of spines, pores, glands, chitinized areas, and modified hairs.

The young males are similar to the females but usually after the second molt they form a cocoon or remain under the shell and go through a more complete metamorphosis, emerging as minute or small, active, apterous or winged insects with regularly segmented bodies, well-developed antennæ, 10- or more-segmented; (branched in the African *Neomargarodes* Green); prominent, simple eyes or ocellanæ in single or double groups; abortive mouth parts; one pair of delicate wings of very simple venation; and a pair of rudimentary hind wings or halteres; two long anal hairs supporting wax in life; and a long penis. In some species both winged and apterous forms are present, and in others males have not been observed at all.

Scale insects are free-living on the roots or tops of plants or inhabit galls or pseudogalls and are frequently found in ants' nests. Like aphids and some

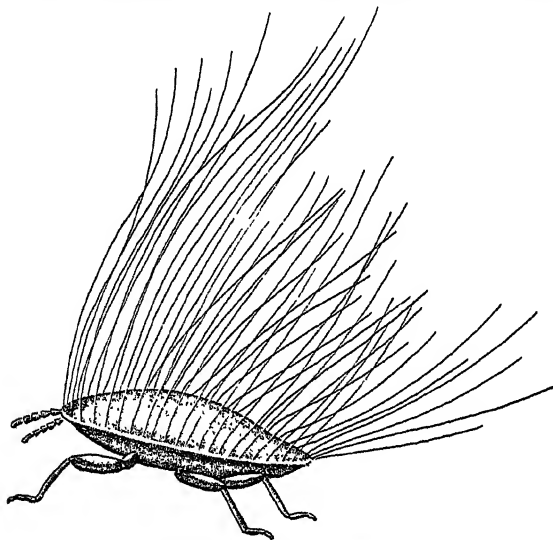


FIG. 117. 1st instar larva of the coccid, *Walkeriana ovilla* Green. Its long silken filaments enable it to be carried by the wind like thistle-down. (Redrawn from Green.)

other members of the HOMOPTERA, scale insects, with the exception of the armored forms (DIASPIDIDÆ), secrete quantities of honeydew which covers the foliage of the hosts and the vegetation, soil, and other objects beneath the hosts. This sticky material is not only unsightly and obnoxious but is the food of a black smut fungus which, with accumulating dust and the countless numbers of ants, flies, bees, wasps, and other insects attracted by the sweet exudate, makes the presence of most scale insects very undesirable. However, it should be pointed out that honeybees convert honeydew into honey and that this secretion has otherwise been utilized to some extent as a food for human beings. Coccids are cosmopolitan in distribution, and about 2,500

species have been described. In Australia and New Zealand eight families are represented, and the group probably attains its greatest development there.

For the most part the members of this superfamily are to be considered injurious because of their great numbers and their damage to native and cultivated plants. A number of species, however, have produced or still produce articles of great commercial value that add greatly to the wealth of certain countries.

Collecting and Mounting.

Scale insects occur abundantly in all regions where there are forests and shrubbery and have become generally well established in orchards and ornamental plantings. Therefore they are not difficult to find. They may be collected in pasteboard boxes, bags, and in liquid preservatives and kept in many different ways. A common method is to dry the specimens *in situ* on portions of the bark, twigs, leaves, roots, or fruit of the host and file or mount these in suitable small boxes, glass vials, riker mounts, or in opaque or transparent envelopes together with necessary data, including the common and scientific names, host, locality, date of collecting, name of collector, and name of determiner. The soft mealybugs and other unarmored forms may also be indefinitely preserved in alcohol.

For study and permanent preservation, scale insects should be mounted on glass microscopic slides. Many methods may be employed in the preparation of such mounts, those given here being simple and easy to master. The procedure may be summarized as follows:

1. Remove the bodies of the males and females from the host and from the protecting scales where present.
2. Wet and dissolve the waxy covering in alcohol, xylol, or other solvent.
3. Transfer to a 10 per cent solution of KOH to remove body contents. Specimens may be boiled a few minutes in a test tube over a small flame or placed in small vials or covered dishes in a warming oven at 100°F for 24 to 48 hours.
4. Body contents, especially eggs and embryos, should then be removed by puncturing the wall and teasing them out with a flattened needle point bent to a 35-degree angle, thus leaving a complete and perfectly clear and clean skin.
5. Transfer to glacial acetic acid, remove all adhering particles, and press out any KOH. For large specimens it is desirable to change the acid at least once.
6. Specimens may be stained with any reliable stains, such as acid fuchsin or magenta red or fast green. The time required depends upon the concentration of the staining medium. Ordinarily the stain may be added to the acetic acid in step 5. It is advisable to mount a few cleared specimens along with the stained ones to show pigmentation.
7. Destaining or washing out the surplus dye may be accomplished by teasing or by heating in a fresh supply of acetic acid for a few minutes.

8. Cleared, stained, and unstained specimens may then be further cleared for 5 to 10 minutes in a mixture of acetic acid 1 part to xylol 2 parts, or in xylol, clove oil, or cedar oil. Specimens left in straight xylol or oils may become very brittle. Xylol may also reduce the brilliance of the red stains.
9. Transfer to and mount directly in canada balsam. The acetic acid should be removed in alcohol before clearing if euparal or certain other mounting media are used.

The classification of the coccids is undergoing constant revision. Where only one family was known a few years ago, no less than 13 families are recognized at present by some workers. I am following Ferris in the arrangement of genera in the different families. Nine important families are included in the following brief discussion.

Family MARGARODIDÆ (Newstead 1901), Morrison 1927 (Mar'ga-ro'di-dæ, from the Greek *μαργαρώδης*, pearl-like; referring to the lustrous cysts which are strung like pearls for necklaces). Giant Coccids, Marsupial Coccids, Ground Pearls.

This family is composed of several groups which are separated into three or more distinct families by some authors. The females are large, rotund forms

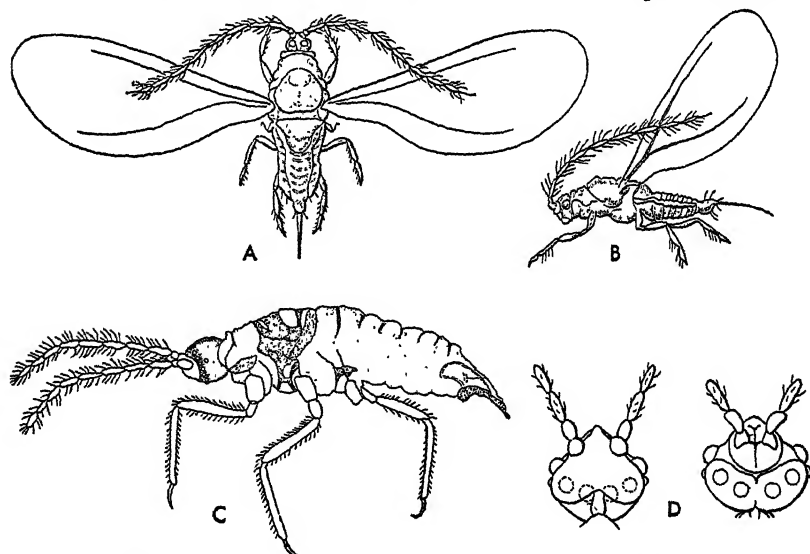


FIG. 118. Male scale insects. A, *Chionaspis elongata* Green; B, *Diaspis amygdali* Tryon; C, *Ceroputo ambigua* Fullaway; D, *Lecanium marsupiale* Green; and dorsal and ventral aspects of the head. (A,B,D, after Green; C, after Fullaway.)

with distinctly segmented bodies often hidden beneath or in waxy secretions. Eyes are absent or represented by a pair of ocellanæ. The legs are well de-

veloped, reduced, or atrophied and with or without segmentation; the fore pair may be greatly enlarged and fossorial and the only pair present in certain rare forms; tarsi one- or two-segmented; thoracic and abdominal spiracles present in all stages; anus dorsal or apical; anal tube obscure or well developed. Males have conspicuous or poorly formed compound eyes, and a pair of ocellanæ may be present in some forms; antennæ 10-segmented, simple or pectinate; halteres with from four to six curved apical bristles.

The family is a comparatively small one but is widely distributed in all parts of the world. The most important genera are: *Aspidoproctus* Newstead, *Callipappus* Guérin, *Icerya* Signoret, *Kuwania* Cockerell, *Llaveia* Signoret, *Margarodes* Guilding, *Matsucoccus* Cockerell, *Monophlebus* Burmeister, and *Xylococcus* Loew.

The largest specimens, which belong to the genera *Llaveia* and *Callipappus*, measure up to 25 mm. in length. The former occurs mostly in tropical America with a representative in the Philippine Islands. The most interesting member of this genus is *L. axin* (Llave) of Mexico from which a fatty substance and acid obtained by the natives are used for making varnish and as a resolvent for healing wounds. *Callipappus* is Australian. In the two species *C. australis* Maskell and *C. westwoodi* Guérin, the females measure up to 25 mm. and the males have a wing expanse of 12 mm.

The latter are red with rosy wings and are commonly called "Bird of Paradise flies" (Tillyard, 1926).

The very young larvæ of *Aspidoproctus cinerea* (Green) and related species of India have a fringe of long transparent wax filaments around the body and are carried by the wind like thistledown (Lefroy, 1909).



FIG. 119. A string of South African ground pearls or cysts of the subterranean coccid, *Margarodes capensis* Giard, and a single cyst greatly enlarged. These beads are the color of old gold, and are very light, and do not discolor the clothes or skin of the wearer.

Members of the unique genus *Margarodes* live on the roots of plants and have fossorial forelegs for digging in the soil. The females are enclosed in wax cysts formed of overlapping plates which have a metallic gold- or bronze-like luster and are gathered and worn like beads by the natives wherever the insects occur. They are also commonly referred to as ground pearls. The females under unfavorable conditions may remain quiescent in these cysts for 1 or more years. They then emerge after rains, become active, and resemble mealybugs in appearance. Species are to be found mostly in the tropical and temperate regions in all parts of the world, but their subterranean habits make them difficult to collect except in a few localities. Several species are known to feed upon the roots of the grape, and some occur in termites' and ants' nests. Certain species are odorous. *M. capensis* Giard, with cysts 7 mm. in diameter, is a well known species in South Africa. *M. trimeni* Giard, common in termite nests of South Africa, is gathered and strung as beads by the natives and worn or sold as "ants' eggs" at Capetown (Brain, 1929). *M. polonicus* (Linn.), the "scarlet grain" of Poland and eastern Europe, was early used as a source of dye and was an article of trade of some importance. It lives on the roots of *Scleranthus annuus*. The North American species include *M. hiemalis* Cockerell from New Mexico and *M. formicarum* Ckll. and *M. rileyi* Giard from the West Indies and Florida. Ferris (1919) notes an interesting case of *M. vitium* Giard, a pest on the roots of grapes in Chile and Venezuela. Specimens in cysts were collected in Chile in 1899 or 1900; and in 1917, when several of the dry cysts in the collection were opened, one female was believed to be still alive after 17 years without food!

Family ORTHEZIIDÆ (Green 1896 as ORTHEZITES), Enderlein 1920.

(Or'thez-i'i-dæ; named after the Abbé Orthez or D'orthes who discovered it in France). Ensign Coccids.

The members of this small family are largely Nearctic, Neotropical, and Palearctic. Two species, *Orthezia cataphracta* (Shaw), a species common to Europe and Siberia, and *O. occidentalis* Douglas, an inhabitant of western North America, live within the north polar region, the former in Greenland and the latter in Alaska, where they subsist on the roots of plants. The family is not represented in the Ethiopian, Oriental, or Australian regions. The females are covered with hard white waxy plates and often carry a large wax egg sac or marsupium at the posterior end. The bodies are elongate-oval, convex, distinctly segmented; one pair of ocellanæ on tubercles; prominent four- to nine-segmented antennæ; two-segmented rostrum; normal legs; thoracic and abdominal spiracles; and anal ring bearing pores and six anal ring setæ. The males usually have well-developed compound eyes; some with three ocelli; setiform nine-segmented antennæ; sheath of penis divided; small style. The one important species is *Orthezia insignis* Douglas, a tropical form commonly known as the greenhouse orthezia because of its wide dissemination on ornamental plants in greenhouses throughout the world. *O. urticae* (Linn.), the type species, is common on many hosts in Europe and Asia.

Family **LACCIFERIDÆ**¹ Chamberlin 1925 (Lac'ci-fer'i-dæ, from the Hindu *lac*, meaning a hundred thousand; referring to the great numbers of individuals). Lac Insects.

A highly specialized group of coccids, the bodies of which are encased in a resinous or lac cell with openings to permit the necessary functions of life. They are largely limited to the tropical, subtropical, and warmer temperate regions except Europe. In the females the bodies are irregularly globular or nearly so

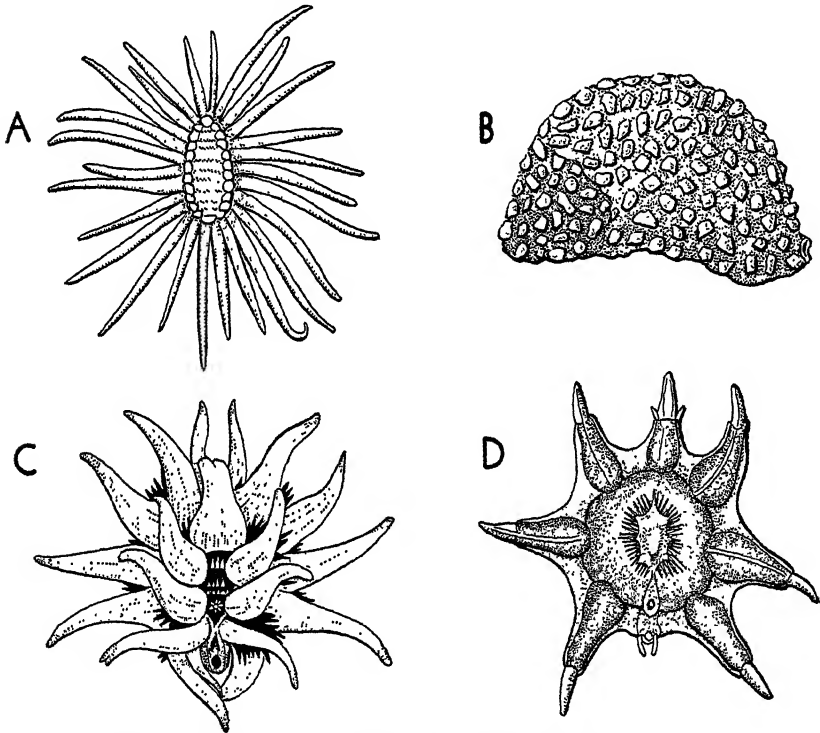


FIG. 120. Some tropical coccids. A, *Phenacoccus ornatus* Green of India; B, *Ceroplastodes cajani* (Maskell) of India and China; C, *Cerococcus albopictus* Green of India; D, *Vinsonia stellifera* (Westwood) widely distributed in the tropics of the Old World. (Redrawn from Green.)

with three processes, one bearing the anus and the other two the pair of mesothoracic spiracles; legs are absent; abdominal spiracles absent; antennæ minute, vestigial, three- to four-segmented; rostrum two-segmented; legs absent; anal end prolonged and tubular with anus on a prominent process and with anal ring and anal ring setæ. The males have one pair of dorsal and one pair of ventral ocelli; are winged or apterous; and the stylus is one half the length of the ab-

¹ Also known as TACHARDIIDÆ Green 1896.

domen. There are only four important genera: *Laccifer* Oken, *Tachardia* Signoret, *Tachardiella* Cockerell, and *Tachardina* Ckll.

By far the most important species in the order and one of the most valuable and useful animals known is the Indian lac insect, *Laccifer lacca* (Kern) (*Tachardia*). It thrives on native fig, banyan, *Rhamnus*, *Bueta*, *Acacia*, *Zizyphus*, *Shorea*, *Schleichera*, and in all on 30 host plants in certain parts of India, Ceylon, Thailand, Indo-China, Formosa, Philippine Islands, and the East Indies. The females are viviparous, sexual, and parthenogenetic, and the tiny males are apterous or winged. The bodies of the females are encased in such a copious exudation of wax or lac that the limbs of the hosts, which are crowded with the insects, are completely enveloped in a coating from $\frac{1}{4}$ to $\frac{1}{2}$ in. thick. This lac is gathered by pruning off the twigs and is melted off in boiling water, refined, and prepared for the market as shell-lac or shellac. It is exported in great quantities and is extensively used in the preparation of varnishes and paints and for a great many other purposes. The yearly output amounts to about 4,000,000 pounds in weight a year.

There are usually two generations of the insect a year, a summer and a winter brood, but in some places a third brood is developed. In ancient times the bodies of the insects were used to make a red or vermilion dye, the color of which is now generally known as carmine or crimson lake. This dye is less intense but more permanent than cochineal. While now it has little commercial importance, it is still used by some Indian women, other than the Hindus, to color the soles of the feet and to some extent to dye silks.

A number of species of *Tachardiella*, notably *T. larræ* (Comstock), *T. cornuta* (Ckll.), *T. fulgens* (Ckll.), and *T. glomerella* Ckll., occur in the semiarid regions of southwestern United States and in Mexico. They all produce lac, some of which is beautifully colored and was used by the Indians to waterproof baskets, to back the bows, to repair pottery, and for other purposes. The bodies of *T. fulgens* were also used as a cure for lung and stomach troubles. None of these species is sufficiently abundant to be of commercial importance.

Family KERMIDÆ Ferris 1937 (Ker'mi-dæ, from the Arabic and Persian *qirmiz*, crimson; referring to the red bodies of the females from which red dyes were obtained). Kermes or Gall-like Coccids.

The mature females are oval, spherical, robust, or hemispherical, and the epidermis is soft, leathery or hard, smooth, punctured, pulverulent, or covered with cottony wax and may be somewhat convoluted. The segmentation is fairly distinct, obscure, or absent; antennæ rudimentary or well formed, six-segmented; rostrum small, two-segmented; legs absent, rudimentary, or normally developed; thoracic spiracles present; anal lobes rarely present. The males have five pairs of ocellanæ, two anal filaments, and a short stylus. The immature forms are flattened, and usually have an anal ring and anal ring setæ.

The family, as now constituted, contains a number of important genera such as *Cryptococcus* Douglas, *Eriococcus* Targioni, *Fonscolombia* Lichtenstein, *Gossyparia* Signoret, *Kermes* Boitard, *Olliffiella* Ckll., and *Trabutina* Marchal.

The tamarisk manna scale, *Trabulina mannifera* (Ehrenberg) [*Gossyparia mannifera* (Hardwick)], *Coccus manniparus* Ehrenb., (*Chermes*)], is a notable member of the family and famous in Biblical accounts because it produced the "manna of the wilderness." This coccid feeds upon *Tamarix mannifera* and

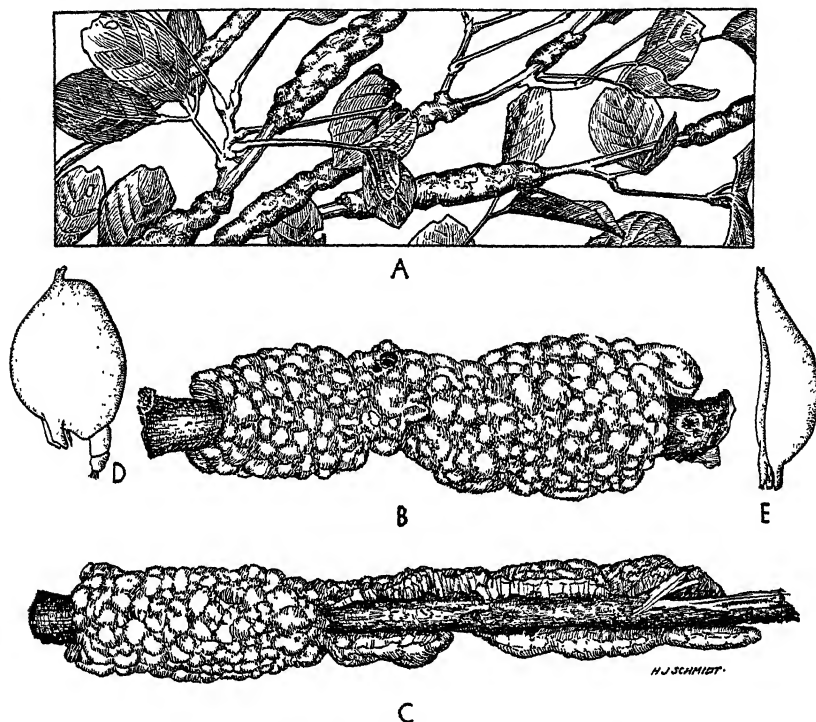


FIG. 121. The Indian lac insect, *Laccifer lacca* (Kern). A, normal appearance of a colony of lac on a living tree; B, stick lac; C, stick lac with section removed from twig to show incrustation of lac over and around the bodies of the insects and the twig which are obliterated from view; D and E, different aspects of the female bodies removed from the lac. (D and E, after Green.)

T. gallica in parts of Asia Minor and in Iraq. The females secrete quantities of honeydew. In arid regions, this material accumulated, stratified with the leaves of the host plant, and solidified throughout the ages to form the sweet food called manna¹ or gift of God by the Israelites wandering in the Sinai wilderness. The material is still collected and used for sugar by the Arabs in the Sinai Mountains and by certain natives of Iraq.

Members of the genus *Eriococcus* are often completely or partially enclosed in felt-like sacs.

¹ According to Weber (*Biol. der Hemipteren*, Springer, Berlin, 1930) manna is composed of 55 per cent cane sugar, 25 per cent invert sugar, and 19.3 per cent dextrin (Wigglesworth, 1939).

The elm scale, *Eriococcus spurius* Modeer (*Gossyparia ulmi* Sign.), is a common serious pest of ornamental elm trees in Europe and North America.

Members of the genus *Kermes* Boitard live on the twigs of oak trees and, because of their spherical shapes and coloration, greatly resemble very small cynipid oak galls. The adult forms have a hard epidermis and are devoid of legs. *K. ilicis* (Linn.) of Europe and western Asia produced *granum tinctorium* or red dye used from the time of Moses and superseded by the more brilliant cochineal after the discovery of the latter in Mexico by the Spanish in 1518. A number of species of *Kermes*, including the European *K. quercus* (Linn.), occur in various parts of the United States.

Family DACTYLOPIIDÆ Maskell 1887 (Dac'ty-lop-i'i-dæ, from the Greek δάκτυλος, finger, + πῖλον, fat, plump; referring to the form of the bodies).
Cochineal Insects.

The members of this family are similar to the mealybugs in appearance and habits. They are 2-3 mm. long, usually red or crimson, and are covered by or rest upon masses of white cottony wax secretions in a matrix of which they lay their eggs. The females are broadly elongate-oval, convex, flattened ventrally; distinctly semented; antennæ small, five- to seven-segmented; one pair of ocellanæ; rostrum two-segmented; legs small, hidden beneath the body; thoracic spiracles present. The males have three pairs of ocellanæ; two long caudal filaments or wax threads; and minute stylus.

This small family is composed of but two genera, *Dactylopius* Costa and *Epicoccus* Cockerell. The most important species is the cochineal, *Dactylopius coccus* Costa, which feeds upon opuntia cacti and was long used by the natives of Mexico for preparing a crimson dye. The value of this new product was recognized by the Spanish in 1518, and exportations to Europe continued from that time until a cochineal industry was established in the Canary Islands in 1826. There it reached its height between 1831 and 1874, when the discovery and perfection of aniline dyes almost obliterated the culture of cochineal. The insect is raised chiefly on nopal, *Nopalea coccinellifera*, and species of *Opuntia*. When the female insects are mature they are brushed from the cacti, dried, and cleaned, and are ready for market. Such specimens may now be purchased from any pharmacist. Dyes are obtained by extracting the body pigments, and variations in color tones are secured by the use of mordants which produce brighter and more beautiful hues. At the present time cochineal dyes are used chiefly for artificial coloring of foods, drinks, and cosmetics.

Family PSEUDOCOCCIDÆ (Heymons 1915) (as PSEUDOCOCCINÆ)
(Pseud'do-coc'ci-dæ, from the Greek ψευδής, false, + κόκκος, a seed or grain). Mealybugs.

A large family of destructive coccids, the members of which are elongate-oval, soft, with distinct segmentation, and usually covered with mealy or cottony wax secretion which may protrude as short lateral and longer anal filaments. The females are further characterized by having well-developed legs;

antennæ absent, reduced, or nine-segmented; one pair of ocellanæ; anal lobes, anal ring, and anal ring setæ present. The eggs are frequently laid in loose masses of cottony wax or felt-like ovisacs. Some forms are viviparous. The males are delicate, apterous or winged insects with two long caudal wax filaments and with one to three or more pairs of ocellanæ.

Mealybugs occur on the tops and on the roots of the host plants and are often sufficiently abundant to do great damage to cultivated and ornamental plantings. They occur throughout the world and are counted among the most destructive pests. The most important genera are *Antonina* Signoret, *Cryptoripersia* Ckll., *Phenacoccus* Ckll., *Pseudococcus* Westwood, *Puto* Signoret (*Ceroputo* Sulc), *Rhizoecus* Künckel, *Ripersia* Signoret, *Ripersiella* Ckll., and *Trionymus* Berg.

The genus *Pseudococcus* is the largest and contains the most important species. It includes such conspicuous species as the citrus mealybug, *P. citri* (Risso), and the citrophilus mealybug, *P. fragilis* Brain (= *gahani* Green), which are now cosmopolitan in and outside greenhouses and in many tropical and subtropical regions; the sugar-cane mealybugs, *P. calceolaria* (Maskel) and *P. sacchari* Ckll., on sugar cane and sorghums in areas where these plants are cultivated; the coffee mealybugs, *P. lilacinus* Ckll. and *P. kenyæ* Le Pelley, serious pests of coffee in Central and Eastern Africa; Comstock's mealybug, *P. comstocki* Kuwana, on citrus and a variety of plants in China and Japan, and introduced by commerce into North America and elsewhere; *P. filamentosus* Ckll. on coffee and many hosts in the tropics; and the pineapple mealybug, *P. brevipes* (Ckll), on pineapple and other hosts in Hawaii, South America, and South Sea Islands.



FIG. 122. The citrophilus mealybug, *Pseudococcus fragilis* Brain. A colony of females. (From *Insects of Western North America*.)

The ground mealybug, *Rhizoecus terrestris* (Newstead), is a minute species infesting the roots of grasses and innumerable agricultural and ornamental plants. It is a European species now distributed in a number of localities in California.

Family ASTEROLECANIIDÆ (Berlese 1898) (as ASTEROLECANIINÆ), Enderlein 1920, (As'ter-o'le-can-i'i-dæ, from the Greek ἀστήρ, a star, + λεκάνη, a little pan or dish; referring to a star-like *Lecanium* or flat scale). Ceravitreous Coccids, Pit Scales.

Small, elongate-oval, convex scales with obscure segmentation, and usually smooth naked bodies which may be covered by a transparent or a tough waxy covering with a fringe or may be embedded in a mass of wax. The antennæ are simple, reduced, or four- to six-segmented; rostrum short, one-segmented; eyes absent; legs vestigial or absent; anal ring with or without anal ring setæ; anal lobes normally present.

These coccids are quite variable in form and habits. The important genera are *Amorphococcus* Green, *Asterolecanium* Targioni, *Cerococcus* Comstock, *Lecaniodiaspis* Targioni, *Mycetococcus* Ferris, and *Pollinia* Targioni.

The pit-making oak scale, *Asterolecanium variolosum* (Ratzeburg), is a brilliant golden or green species embedded in pits on the twigs of oak and olive trees in Europe and North America. The oak wax scale, *Cerococcus quercus* Comstock, is completely encased in a large mass of yellow wax from 4-6 mm. in diameter. It infests the twigs of oak in California and Arizona, and the wax was once gathered by the Indians for chewing gum.

Family COCCIDÆ Stephens 1829 (Coc'ci-dæ, from the Greek κόκκος, a seed; from their resemblance to a seed). Soft Scales, Tortoise Scales.

This large family is composed of a number of variable genera and is one of considerable economic importance. The members are more or less active throughout all stages, except some that are fixed in the last stage. The adult females are elongate-oval and flattened or nearly hemispherical or globular in form; with leathery or hard exoskeleton which is smooth, roughened, naked or slightly covered with wax; segmentation obscure; antennæ absent, small or seven- to eight-segmented; one pair of ocellanæ; rostrum short, simple; legs absent, reduced, or present; anal cleft and a pair of dorsal anal plates or opercula usually present; anal ring with six to 10 or more anal ring setæ present or absent. Males apterous or winged; with a variable number of ocellanæ; and stylus short and blunt.

Among the many genera are *Ceroplastes* Gray, *Coccus* Linn., *Ericerus* Westwood, *Eriopeltis* Signoret, *Eucalymnatus* Cockerell, *Lecanium* Burmeister, *Physokermes* Targioni, *Pulvinaria* Targioni, *Saissetia* Deplanches, and *Toumeyella* Ckll.

The soft brown scale, *Coccus hesperidum* Linn., is a tropical and subtropical species occurring on a large number of host plants and distributed with greenhouse stock throughout the temperate regions of the world.

The Chinese wax scale or *pe-la*, *Ericerus pe-la* Chavannes, is a most interesting insect. The males secrete a pure white wax which envelops their bodies and is gathered in quantity for making candles and for other useful purposes. The coccid occurs in China and Japan and lives upon *Rhus*, *Ligustrum*, *Hibiscus*, and *Fraxinus*. In the province of Shantung, China, the insects are reared to produce wax, the species being preserved indoors during the winter and placed on the wild deciduous hosts in the spring. In the province of Kiangsi, the insects are reared on the evergreen *Rhus* and *Hibiscus* and are carried by night to the mountains of Kiatingfu in the southern part of Szechuan, where the young

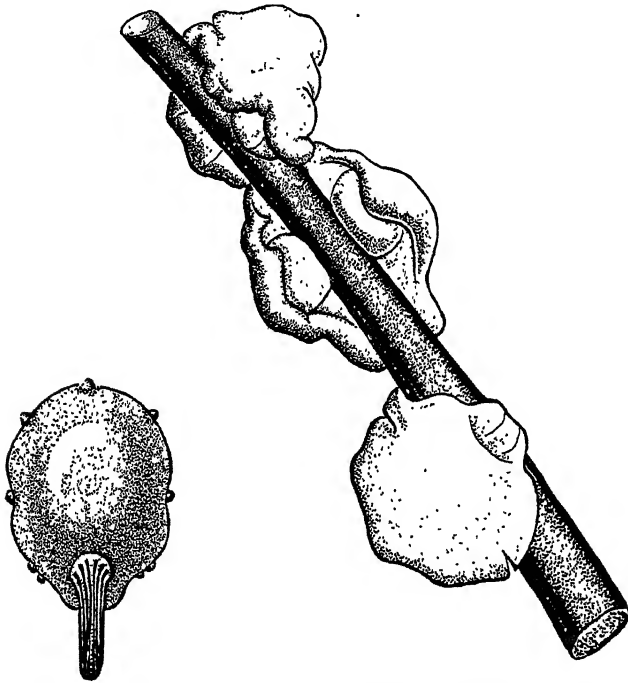


FIG. 123. A colony of the wax scale, *Ceroplastes ceriferus* (Anderson), appears like lumps of dough stuck to the twigs of plants. (Redrawn from Green.)

are colonized on the native deciduous *Ligustrum* and *Fraxinus*. The scales mature in the late summer and, with the wax, are then gathered, after which the colonies completely die out only to be replenished from Kiangsi the next spring. This practice has been going on for centuries, but cheaper paraffin is reducing somewhat the formerly large production of the costlier wax. About 2,800 tons of wax are produced annually in Szechuan. (Chiao and Pen. *Rev. Appld. Ent.*, Ser. A. 29: 153, 1941.)

The wax scales of the genus *Ceroplastes* are also producers of white wax. The Indian wax scale, *C. ceriferus* Anderson, of China and India not only

surrounds its body with useful wax but also is valued as a medicine in the latter country. It is nevertheless also a destructive pest in China, India, Japan, Australia, and other tropical and subtropical regions. *C. destructor* (Signoret) is a pest of citrus and coffee in Kenya, Africa, and of citrus in the South Sea Islands and Australia. *C. floridensis* Comstock is a tropical and subtropical coccid on citrus, mango, persimmon, and tea in both the Old and the New Worlds and is a pest of importance in parts of Australia.

The *nigra* scale, *Saissetia nigra* (Neitner), and the *black scale*, *S. oleæ* (Bernard), are tropical coccids which have been widely distributed by plant materials throughout the warmer temperate regions and in greenhouses in cooler regions. Both are omnivorous feeders. The former is an important pest of cotton, coffee, and other tropical plants while the latter is especially injurious to citrus, apricot, oleander, and pepper trees, to olives, and to many other fruit and ornamental trees and shrubs in subtropical regions and particularly in the Mediterranean area, California, South Africa, Australia, and Japan. The *hemispherical scale*, *S. hemisphærica* (Targioni), is a frequent pest of ferns and occurs commonly on a number of plants in greenhouses and homes.

Family DIASPIDIDÆ Maskell 1878 (Di'as-pid'i-dæ, from the Greek *διδ*, in the midst of, + *ἀσπίς*, a round shield; referring to the shield-like scale secreted over the bodies). Armored Scales, Scale Insects.

This is by far the largest family in the superfamily and is destined to be separated into a number of families as systematic investigation of the species progresses. The members are very small and are hidden under a single scale or more often encased between a tough upper and a much thinner under scale. The scales are formed from wax secreted by special glands opening dorsally and ventrally at the posterior end or pygidium. The scales are spun at the end of or around the first and second cast skins or exuviae. They vary in shape from circular to subcircular, elongate, linear or thread-like, or oystershell-shaped. The surface may be flat, convex, or cone-shaped; smooth or ridged; thin and delicate or hard and tough; and variously colored white, gray, yellow, and different shades of brown, dull red, and black. Those of the male are much smaller and usually more elongated in form and sometimes paler in color.

The bodies of the adult females are very small, disk-like or elongated, with the body segmentation obscure and with abdominal segments II to VIII inclusive fused into a distinct region called the *pygidium* which is highly specialized for secreting and molding the shells and for reproduction. The various structures that are of great taxonomic value are shown in the accompanying illustrations. The antennae are absent or vestigial; eyes and legs absent; rostrum short and simple; two pairs of thoracic spiracles present; anus dorsal. The males are minute, apterous or winged; with well-developed antennae; three pairs of ocellae; two anal filaments; and stylus long and slender. They apparently take no food.

Reproduction is sexual or parthenogenetic; viviparous and oviparous. The nearly microscopic eggs are laid under the scales, which are extended to accom-

modate them, and after the females die the scales may furnish protection for the eggs during winter. The eggs vary in color from white to yellow, red, or purple. The newly hatched young are scarcely visible to the naked eye. They are oval with distinctly segmented body, including nine abdominal segments and two long anal filaments. The antennæ are usually six-segmented; one pair of ocellanæ; three pairs of legs with two pairs of digitules at the ends of the tarsi; one-segmented rostrum; and dorsal anus. They are active crawlers and con-

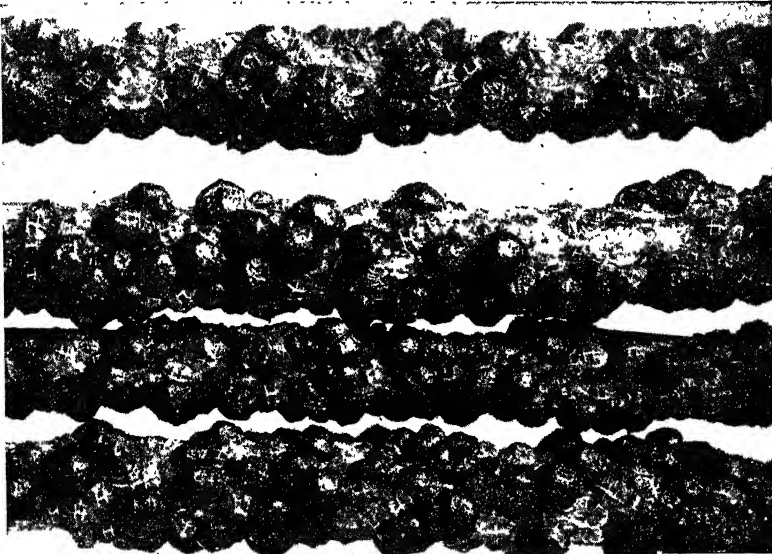


FIG. 124. The black scale, *Saisssetia oleæ* (Bernard), on oleander. This is a widely distributed species in the tropical and subtropical regions and also occurs in greenhouses elsewhere. (From *Insects of Western North America*.)

tinue to move until suitable feeding places are found or until failing strength and fatigue cause death. They may live several days and travel considerable distances, but they may also be distributed by wind, birds, other insects, farm equipment, and on the clothes of man. Frequently some of them crowd around the females and may even settle on their wasting scales. Thus compact colonies are formed on the host plants, which may become encrusted with the scales. The armored scales apparently excrete very little honeydew, since no evidences of this sticky material is to be found upon the plants infested by them.

Certain species appear to inject harmful toxins into the hosts and produce irregularities in the growth of the tissues, discoloration and death to portions of or to the entire plant. They feed primarily upon perennial shrubs and trees. A number of species are restricted to a single host, others to a single genus or family, but very many are omnivorous and may infest several hundred differ-

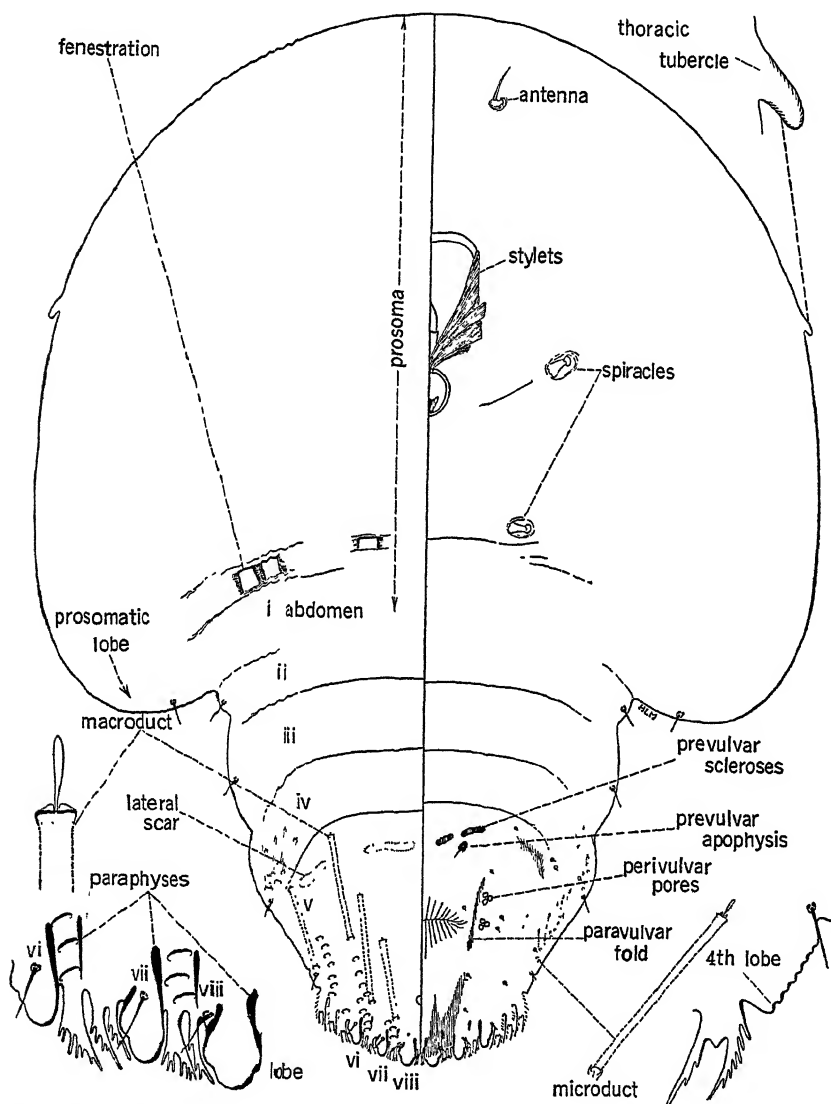


FIG. 125. A generalized and semi-diagrammatic drawing representing anatomical features of the armored scales belonging to the genus *Aonidiella*. (Drawing by H. L. McKenzie.)

ent kinds of plants. Their distribution includes much of the world wherever suitable food plants occur.

There are many genera, of which the following may be mentioned: *Aonidia* Targioni, *Aonidiella* Berlese and Leonardi, *Aspidaspis* Ferris, *Aspidiotus* Bouché, *Aulacaspis* Cockerell, *Chionaspis* Signoret, *Chrysomphalus* Ashmead, *Clavaspis* MacGillivray, *Diaspidiotus* Leonardi, *Diaspis* Costa, *Epidiaspis* Ckll., *Fiorinia* Targioni, *Hemiberlesia* Ckll., *Hemichionaspis* Ckll., *Howardia* Berlese and Leonardi, *Ischnaspis* Douglas, *Lepidosaphes* Shimer, *Odonaspis* Leonardi, *Parlatoria* Targioni, *Phenacaspis* Ckll., *Pinnaspis* Ckll., *Protodiaspis* Ckll., *Pseudaonidia* Ckll., *Quadraspidotus* MacGillivray, and *Targionia* Signoret. It is impossible, for lack of space, to discuss any considerable number of the members of even these few genera.

The genus *Aonidiella*, which now contains a number of species previously placed in the genus *Chrysomphalus*, embraces a relatively few species which occur chiefly in Africa and across southern Asia as far as southern Japan. The most important member is the red scale, *Aonidiella aurantii* (Maskell), distinguished by its conspicuous, reddish, circular scale. It is a serious pest to citrus and other subtropical plants in California, Florida, Australia, Palestine, and other subtropical regions. Further representatives of this group are the yellow scale, *A. citrina* (Coquillett), of California, Texas, India, and Japan, on citrus and various hosts; and the Chinese red scale, *A. taxus* Leonardi, of China, Japan, and East Asia, on *Taxus* and *Podocarpus* and distributed to southern Europe (it has long been confused with the common red scale), both being Old World species that are now well-known pests of ornamental and subtropical fruits and have become widely distributed on nursery plants. They may be pests in greenhouses in temperate climates.

A near relative of the above species is the Florida red scale, *Chrysomphalus ficus* Ashmead (*Coccus aonidum* Linn.), a species with a reddish-black scale which is a pest of considerable importance to citrus in Florida, Palestine, Egypt, and other parts of the world. It has become widely distributed in commerce and feeds upon a large number of plants. The Spanish red scale, *C. dictyospermi* (Morgan), on citrus and other plants and also in the Mediterranean basin on persimmon, palms, and other plants, is a native of Australia and Indo-Malaysian areas. This species now has a wide distribution in greenhouses.

The genus *Aspidiotus*, once the largest in the family, has been bereft of all except some three species. One of the commonest and most widely distributed is the ivy scale, *Aspidiotus nerii* Bouché (*Chermes hederæ* Vallot), which is especially common on English ivy, oleander, olive, ferns, palms, and umbrella plant out of doors, in greenhouses, and in residences. The coconut palm scale, *Aspidiotus destructor* Signoret, is a serious pest of coconut, many other palms, avocado, tea, banana, guava, mango, and other hosts in tropical and subtropical regions throughout the world.

The San José scale, *Quadraspidotus perniciosus* (Comstock) (*Aspidiotus*), has had a very remarkable history in the annals of economic entomology. It

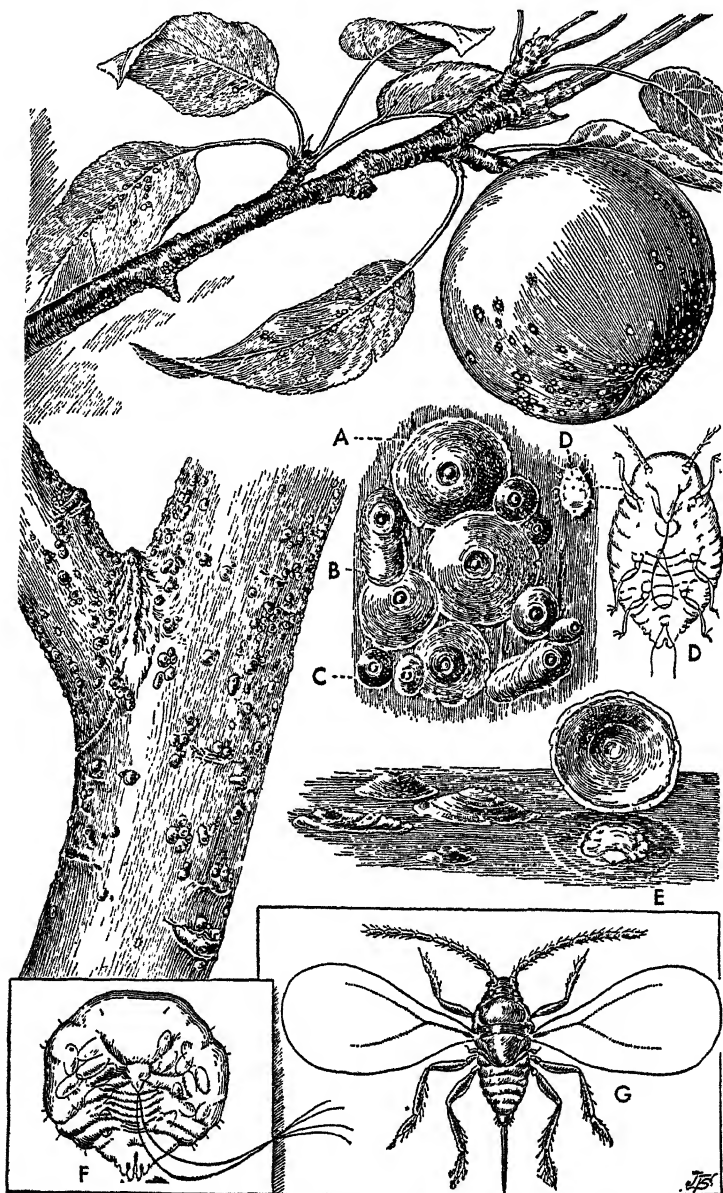


FIG. 126. The San José scale, *Quadraspidiotus perniciosus* (Comstock), infesting apple. A, scale of adult female; B, scale of male; C, 1st instar young; D, same more enlarged; E, scale lifted to expose the female body beneath; F, body of the female; G, adult male. (After U.S.D.A.)

was described in 1880 by Comstock as injurious to fruit trees growing at San Jose, Calif., and subsequently it appeared throughout the United States and elsewhere in temperate and subtropical regions of the world where deciduous fruit trees and ornamental trees and shrubs are grown. It undoubtedly originated in eastern Asia. Other important species, formerly in *Aspidiotus* and now also referred to this genus, are the cherry scale, *Quadraspidiotus forbesi* (Johnson), and the walnut scale, *Q. juglans-regiæ* (Comstock), of North America, and *Q. ostreaformis* (Curtis) on deciduous fruit trees in Europe and North America.

The rose scale, *Aulacaspis rosæ* (Bouché), a red-bodied species with white scales (the scales of the females circular and those of the male minute and carinated), is a cosmopolitan species on *Rubus* and *Rosa*. A more destructive relative is the West Indian peach or mulberry scale, *Aulacaspis pentagona* (Targioni), a tropical and subtropical species which has a wide distribution in Asia, southern Europe, northern Africa, and southern North America. Its depredations on mulberry trees in Italy were claimed to have been checked by the introduction of the aphelinid parasite, *Prospaltella berlese* Howard, from America. This coccid is polyphagous on a wide variety of host plants.

The scurfy scale, *Chionaspis furfura* (Fitch), which appears somewhat like the rose scale, is a common and abundant coccid in eastern North America, where it feeds upon a variety of wild and cultivated trees and shrubs and is a pest of some consequence.

The oystershell scale, *Lepidosaphes ulmi* (Linn.), the scales of which resemble miniature oysters and which cover the bodies of the insects and quantities of white eggs, is perhaps the most widely distributed cosmopolitan species as well as one of the most omnivorous feeders. It is chiefly confined to deciduous trees and shrubs in the temperate regions but also feeds upon evergreen broad-leaved plants. A native of East Asia, it has been disseminated on ornamental plants and fruit trees. It often completely covers the main trunk, limbs, and branches of the trees and may cause the death of the wild hosts over considerable areas. The purple scale, *L. beckii* (Newman), and Glover's scale, *L. gloverii* (Packard), are Old World species distributed chiefly on citrus trees, to which they are quite destructive pests. The Mediterranean fig scale, *L. ficus* (Signoret), is a pest of figs in the Mediterranean basin and has recently become established in the fig orchards of California.

The olive scale, *Parlatoria oleæ* (Colvée), on olives and other hosts; the date palm scale, *P. blanchardii* (Targioni), on date palms; and the black parlatoria, *P. zizyphus* (Lucas), on dates, citrus, jujubes, and other hosts, are all important injurious species in the Mediterranean region and western Asia and have been introduced into many other warm areas (the first two into Arizona and California and the last into Mississippi). *P. theæ* Kkll, is an important pest of tea in eastern Asia. The members of this genus have a very large second exuvia.

The pine leaf scale, *Phenacaspis pinifoliæ* (Fitch) (*Chionaspis*), is one of the commonest and most conspicuous insect pests feeding on pine trees throughout North America. The yellow exuvia, the conspicuous white female scales, and



FIG. 127. A colony of the oystershell scale, *Lepidosaphes ulmi* (Linn.), on the bark of English walnut. The insect bodies and eggs are hidden beneath the scales. Greatly enlarged. (From *A History of Entomology*.)

the tiny carinated male scales occur on the needles almost everywhere in forests, parks, and private grounds.

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CHAPTER XXVI

23. Order MEGALOPTERA Latreille¹ 1802

(Meg'a-lop'ter-a, from the Greek *μεγάλος*, great, + *πτερά*, wings; referring to the large wings of some species.) German, Groszflügler. French, Sialidés.

Alderflies, Humpbackedflies, Orflies, Dobsonflies, Fishflies,
Sialids.

Adults medium-sized to large with complex metamorphosis; prognathous head; biting mouth parts; slender, many-segmented antennæ; large, similar wings held roof-like or nearly flat over the body, veins normally unbranched at margins, hind pair with large anal fold; cerci absent; male gonopods present.

Larvæ aquatic; thysanuriform or eruciform; carnivorous; with short biting mouth parts; and with seven to eight pairs of simple or segmented lateral abdominal gill branches.

EXTERNAL ANATOMY

<i>Adults</i>	<i>Larvæ</i>
Size — small to very large insects with wing expanse as great as 150 mm.	Size — medium to large.
Shape — elongate, slender or robust.	Shape — thysanuriform or somewhat cylindrical, robust.
Exoskeleton — rather soft or hard and well chitinized, smooth or hairy.	Exoskeleton — smooth, tough and leathery, partly chitinized.
Color — usually cryptic or dull.	Color — dull and cryptic.
Head — well developed, hypognathous.	Head — prognathous, wider or narrower than thorax.
<i>Eyes</i> — compound, large and with many facets.	<i>Eyes</i> — simple.
<i>Ocelli</i> — three or absent.	<i>Antennæ</i> — short, setiform, four-segmented.
<i>Antennæ</i> — filiform and many-segmented; moniliform or pectinate.	<i>Mouth parts</i> — biting, strong, similar to those of carabid beetles.
<i>Mouth parts</i> — biting.	Thorax — about as wide as the head.
<i>Mandibles</i> — strong, greatly enlarged in male <i>Corydalus</i> .	<i>Legs</i> — well developed, with paired claws.
<i>Maxillary palpi</i> — five-segmented.	<i>Spiracles</i> — two pairs or none.
<i>Labial palpi</i> — three-segmented.	Abdomen — 10-segmented; with seven or eight pairs of simple or segmented leg-like appendages supposed to function as gills, and with or without a simple ter-
Thorax — normal, the prothorax quadrate or elongated, large and free.	
<i>Legs</i> — normal, similar, <i>tarsi</i> five-segmented.	

¹ Latreille (1802, III: 289-291) first used this name for a family of the NEUROPTERA which included the genera *Chauliodes*, *Corydalus*, *Sialis*, and *Raphidia*, and it is still used to embrace these and related genera. Handlirsch in 1903 and 1906 applied the name as a separate order as here used. Tillyard 1918, Schröder 1925, Stitz 1928, Brues and Melander 1932, Weber 1933, and others have also employed it in this more restricted sense. The RAPHI-DIODEA constitute a separate order.

EXTERNAL ANATOMY—*Continued*

<i>Adults</i>	<i>Larvæ</i>
<i>Wings</i> — two pairs, held roof-like or flat over the body, similar in size and structure, many-veined, veinlets not usually branched at the wing margins, with or without pterostigma. <i>Spiracles</i> — two pairs. <i>Abdomen</i> — 10-segmented. <i>Spiracles</i> — eight pairs. <i>Cerci</i> — absent. <i>Genitalia</i> — not exerted. Male superior and inferior appendages — one or both present.	minal filament or with a pair of hooked anal feet or pygopods. Some with accessory sponge-like gills. <i>Spiracles</i> — eight pairs.

For information on internal anatomy consult the order NEUROPTERA.

The members of this rather small order are aquatic in habits, and, while the adults may be abundant in some places, they are rarely met with in great numbers as are so many other water-loving insects. Their chief economic significance lies in the fact that both the larval and adult forms are highly prized by many fresh-water fishes for food. The adults serve also as models for artificial flies used by fishermen, and the larvæ are extensively used as bait by anglers.

According to Tillyard (1926), "The MEGALOPTERA are undoubtedly a very old group, but their remains are difficult to recognize as fossils; undoubted members of the group first appear in the European Trias."

It is a relatively small order containing about 500 species.

KEY TO FAMILIES — ADULTS

1. Adults with wing expanse of 20–40 mm.; without ocelli; fourth tarsal segment dilated and conspicuously bilobed **SIALIDÆ**
2. Adults with wing expanse of 40–100 mm.; with three ocelli; fourth tarsal segment cylindrical **CORYDALIDÆ** p. 370

LARVÆ

1. Larvæ with seven pairs of segmented lateral abdominal gill filaments; without anal prolegs and with terminal anal filament . . . **SIALIDÆ**
2. Larvæ with eight pairs of unsegmented or imperfectly segmented lateral abdominal gill filaments, with a pair of hooked apical anal prolegs; without terminal anal filament **CORYDALIDÆ** p. 370

Family SIALIDÆ Samouelle 1819 (**SIALIDA** Leach 1815) (Si-al'i-dæ, from the Greek *σάλις*, a kind of bird). German, Wasserflorfliegen. French, Sialidés. Sialids, Alderflies, Orflies, Humpbackedflies.

A rather small family of some four genera and 30 species occurring in various parts of the north and south temperate regions. The adults are for the most

part small, brown or black in color, and rather feeble fliers, but some species are quite agile in their somewhat erratic movements over the surface of the water at dusk. The dominant genus, *Sialis* Latr. is Holarctic and two other

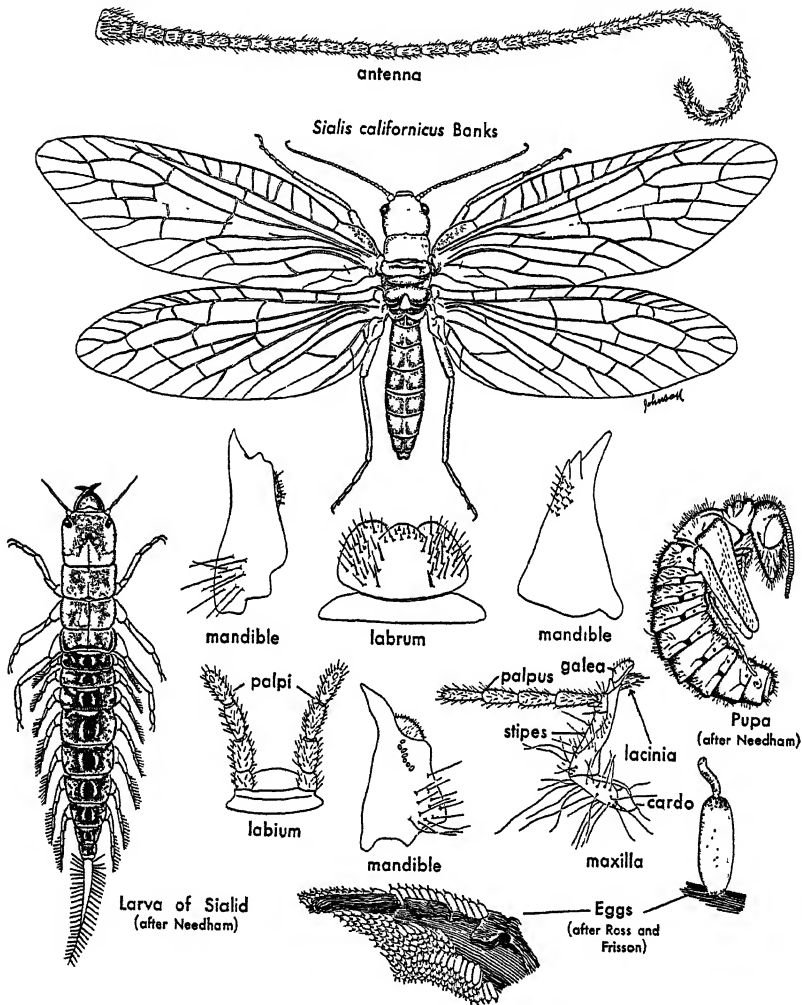


FIG. 128. The California alderfly, *Sialis californicus* Banks, and mouth parts and antennae. The larva, pupa, and eggs are of other species.

genera, *Austrosialis* Tillyard and *Stenosialis* Tillyard, are Australian and Tasmanian.

The luteous alderfly, *Sialis flavilatera* Linn. (*lutaria* Fab.), of northern Europe is brownish-black with yellowish-brown wings. It is a weak and clumsy

flier, and lives but a few days. The minute eggs are elongated, with a small micropylar tubercle at one end, and stone gray in color. They are attached in rows to water plants, a single female being capable of laying several thousand eggs. The larvæ are active, carnivorous, and lie buried in the bottoms of streams. They taper posteriorly, and the abdomen suspends a long unseg-

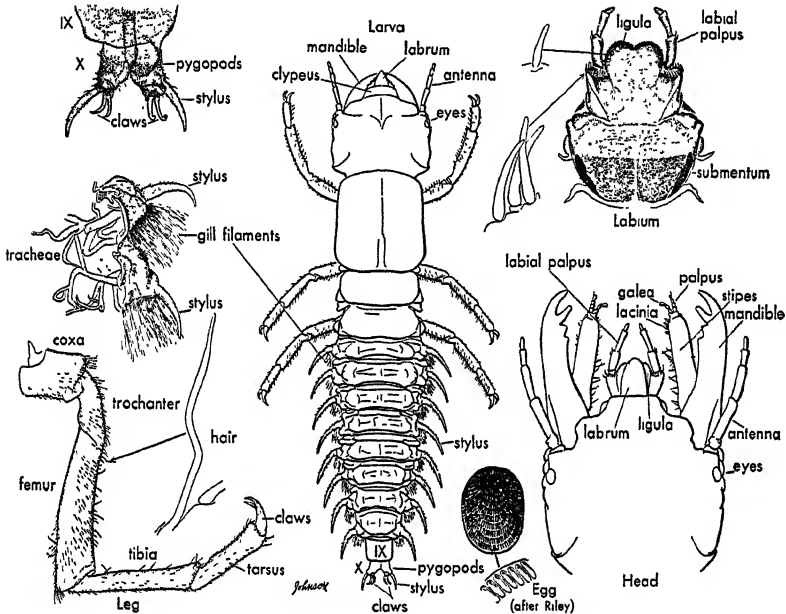


FIG. 129. Egg and larva of the dobsonfly, *Corydalis cornutus* (Linn.), with some anatomical features of the latter. The larvæ are commonly known as "hellgrammites" and are choice fish bait.

mented filament posteriorly, which is much longer than the seven pairs of five-segmented lateral gill filaments. These young feed upon any living prey that they are able to stalk, ambush, and overcome. When ready to pupate, they leave the water and construct a cell in the soil above the water line. The adults are frequently employed as bait by fishermen.

The smoky alderfly, *Sialis infumata* Newman, is a dark-brownish or almost black species with a wing expanse of 25 mm. It has been reported as occurring in many parts of North America, but according to Ross (1937) it is confined to the eastern part of the United States. It usually inhabits swift streams where the active larvæ cling to the lower surfaces of stones, but may also occur along the margins of streams, ponds, and lakes. The eggs are deposited in batches of a single layer. Pupation occurs in an earthen cell out of the water. Ross (1937) has recently monographed the Nearctic species and has dropped the genera *Sembris* Rambur and *Protosialis* Weele, including all these species under the

single genus *Sialis*. These are placed in four groups as follows: California group, seven species; American group, two species; Infumata group, eight species; and the Aequalis group, two species. *Syncordulia atrifrons* McLachlan occurs in Australia.

Family CORYDALIDÆ Burmeister 1839 (**CORYDALIDA** Leach 1815)
(Cor'y-dal'i-dæ, from the Greek *κορυδαλλίς*, a crested lark). Dobsonflies.

This is a family of remarkable aquatic insects, some of which are large and conspicuous. It includes about 16 genera and 80 species. The adults, commonly

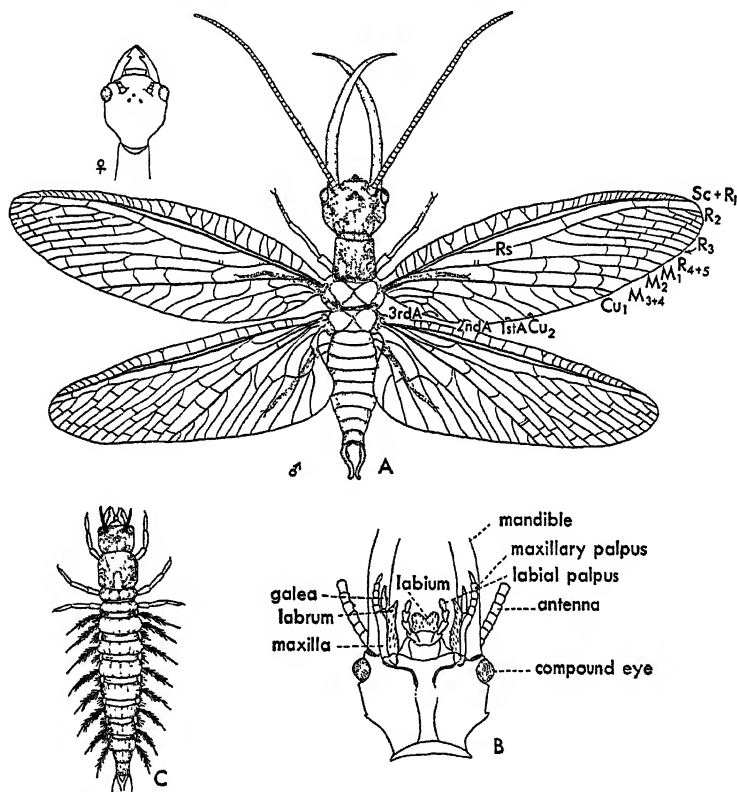


FIG. 130. The dobsonfly, *Corydalus cornutus* (Linn.). A, adult male and head of female; B, head and mouth parts of male; C, larva or "hellgrammite."

referred to as dobsonflies in America, are taken frequently, but not abundantly, in many parts of the country. The larvæ are variously known as "dobsons," "hellgrammites," "conniption bugs," "crawlers," "arnly," and "toe-biters" and are used everywhere as bait for catching fresh-water fish, notably bass

and trout. They are formidable-looking creatures that occur under stones in slow or swift water and are predacious on the naiads of dragonflies, stoneflies, mayflies, and other aquatic forms. Two or three years are required to complete the larval stage, and pupation occurs in a cell constructed under stones, logs, or refuse on the banks out of the water. The eggs are laid in masses of several thousands on branches, rocks, and objects over the water. Adults appear in early summer.

The dobson, *Corydalis cornutus* (Linn.) (*Corydalis*), is probably the most interesting species because of the greatly elongated and horn-like mandibles of the males which are nearly half the length of the body. The length of the adults may vary from 100–130 mm. The species occurs in eastern North America. Its western counterpart, belonging to a separate subfamily, is the smaller California dobson, *Neohermes californicus* (Walker), which is but 43 mm. long. The New Zealand *Archichauliodes dubitatus* (Walker) varies from 50–100 mm. in length. The larvæ are called toe-biters.

The genera *Chlorina* Banks, *Corydalis* Latr., *Platyneuromus* Weele, *Chauliodes* Latr., *Nigronia* Banks, *Neohermes* Banks, and *Protochauliodes* Weele are American; *Acanthacorydalis* Weele, *Hermes* Gray, *Neohermes* Weele, *Neuromus* Rambur, *Ctenochauliodes* Weele, *Neochauliodes* Weele, and *Parachauliodes* Weele are Asiatic; *Archichauliodes* Weele is New Zealand; and *Chloroniella* E. Petersen, *Platychauliodes* E. Petersen, and *Tæniochauliodes* E. Petersen are African.

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CHAPTER XXVII

24. Order NEUROPTERA¹ Linnæus 1758

(Neu-rop'ter-a, from the Greek *νεῦρα*, nerves, + *πτερά*, wings: referring to the many veins in the wings.) German, Echte Netzflügler. French, Les néuroptères.

Nerve-winged Insects, Lacewings.

Minute to medium-sized or rarely large; mostly terrestrial, carnivorous insects with complex metamorphosis; biting mouth parts; head hypognathous, free; compound eyes large and widely separated; ocelli three or wanting; antennæ variable, but usually filiform; legs long and slender, tarsi five-segmented; wings two pairs, normally similar in shape, size, and venation with a network of veins, sometimes hairy and moth-like; cerci absent; ovipositor not exerted.

Larvæ terrestrial excepting the aquatic SISYRIDÆ; carnivorous; thysanuriform, or rarely eruciform; mouth parts piercing and sucking but of biting type; antennæ setiform; legs short and stout; cerci absent.

Although reclassified many times and its number of genera greatly reduced, the insects of this order are still far from homogenous in structure and are widely separated in their biology. For practically every statement made concerning the order there is an exception which serves to indicate the difficulties of summarizing the character and habits of the group as a whole.

IMPORTANT ANATOMICAL CHARACTERS — ADULTS

<i>External</i>	<i>Internal</i>
Size — minute or medium to large.	Digestive System.
Shape — mostly slender, a few robust.	<i>Mouth</i> with fairly large buccal cavity leading to pharynx.
Exoskeleton — thin and often fragile, smooth or hairy; some covered with whitish powdery wax.	<i>Pharynx</i> — with a modified pharyngeal pump.
Color — cryptic, dusky, brown, gray, green, and some brightly colored.	<i>Œsophagus</i> — annulated, dilated somewhat through the thorax and widened in the anterior part of the abdomen into a large food sac.
Head — hypognathous, free, rather small.	<i>Proventriculus</i> — funnel-shaped, lined with spines and bars; arises from under side of œsophagus in the third abdominal segment and leads into the mid-intestine through an œsophageal valve.
<i>Eyes</i> — compound eyes large and widely separated; <i>ocelli</i> — absent except in OSMYLIDÆ and DILARIDÆ which have three.	<i>Mid-intestine</i> — extends nearly to apex of abdomen.
<i>Antennæ</i> — variable, short or long, setiform, filiform, moniliform, pectinate, clavate, or capitate; often many-segmented.	
<i>Mouth parts</i> — simple, typically biting.	

¹ The Linnæan order NEUROPTERA has undergone many revisions since it was first

IMPORTANT ANATOMICAL CHARACTERS — ADULTS — *Continued*

<i>External</i>	<i>Internal</i>
<p><i>Labrum</i> — broad, entire or notched.</p> <p><i>Mandibles</i> — strong, with an apical and often an inner tooth.</p> <p><i>Maxillæ</i> — with lacinia, galea, and five-segmented palpi.</p> <p><i>Hypopharynx</i> — well developed, simple or three-lobed.</p> <p><i>Labium</i> — prominent; ligula reduced or absent; <i>palpi</i> — three-segmented.</p> <p>Thorax — strong with segmentation distinct.</p> <p><i>Prothorax</i> — short or greatly elongated.</p> <p><i>Legs</i> — short and usually slender; with or without spurs; <i>tarsi</i> — five-segmented; usually a pair of claws — rarely simple.</p> <p><i>Wings</i> — two pairs; usually similar in size and shape; variable in a few groups; held roof-like over body at rest; disconnected or joined in flight; venation variable but usually many longitudinal and cross veins present; smooth or hairy; transparent or cloudy or covered with fine, whitish powdery wax; some large and moth-like.</p> <p><i>Spiracles</i> — two pairs; first pair on meso- and second pair on metathorax.</p> <p>Abdomen — usually cylindrical and slender; rarely stout, short or long; 10-segmented, the first short and the last much reduced.</p> <p><i>Cerci</i> — absent.</p> <p><i>Spiracles</i> — eight pairs, one on each of the first eight segments.</p> <p>Genitalia</p> <p><i>Males</i> with single hypandrium or a pair of gonocoxites on the ninth sternite.</p> <p><i>Females</i> with a pair of gonapophyses consisting of inserted ovipositor from the ninth sternite.</p>	<p><i>Malpighian tubes</i> — eight, arising from the mesenteron.</p> <p><i>Hind intestine</i> — extends as narrower tube to rectum, which latter dilates and then constricts into the anus. Six rectal glands present.</p> <p>Circulatory System.</p> <p>Usual.</p> <p>Respiratory System.</p> <p><i>Spiracles</i> — thoracic, two pairs; abdominal, eight pairs.</p> <p>Nervous System.</p> <p><i>Supra-oesophageal ganglion</i> in dorsal part of the head.</p> <p><i>Sub-oesophageal ganglion.</i></p> <p><i>Thoracic ganglia</i> — three.</p> <p><i>Abdominal ganglia</i> — seven, usually one less than in the larva.</p> <p>Reproductive System.</p> <p><i>Male</i> — testes paired or fused, each oval, sometimes twisted. <i>Vesiculæ seminales</i> — large, divided longitudinally; ducts unite to form ejaculatory duct. Only true penis in CONIOPTERYGIDÆ.</p> <p><i>Female</i> — each ovary consists of 12 merioistic polytrophic ovarioles; about 10 egg tubes. Paired cement glands enter vagina — usually only one developed.</p> <p><i>Glands</i> — Salivary — one pair mandibular in head and one pair true salivary mainly in thorax.</p> <p><i>Cement</i> — empty into vagina for egg stalks and egg-adhesive.</p> <p><i>Stink</i> — in prothorax of <i>Chrysopa</i>.</p> <p><i>Scent</i> — in male of <i>Osmylus</i> to attract female.</p> <p><i>Wax</i> — modified hypodermal cells on abdomen of CONIOPTERYGIDÆ similar to those in the COCCOIDEA.</p>

erected in the 10th edition of *Systema Naturæ* in 1758. For many years it has been a repository for all the species now generally referred to as neuropteroid insects. Handlirsch limited it to the present conception in 1903.

Although this is an important order of insects there are still many of its members that are but imperfectly known with the possible exception of the Holarctic CHRYSOPIDÆ and therefore offers the student and investigator a rich field for studies in distribution, biology, and systematics.

IMPORTANT ANATOMICAL CHARACTERS — LARVÆ

<i>External</i>	<i>Internal</i>
<p>Size — minute, to medium.</p> <p>Shape — thysanuriform, robust, or disk-like.</p> <p>Exoskeleton — thin, elastic; with hairs, spines, scales, macrotrichia, microtrichia, dolichasters.*</p> <p>Color — cryptic and dull or green, pinkish, yellow, mottled.</p> <p>Head — well developed, free, prognathous, small in some families, heavily chitinized, strong.</p> <p>Eyes — simple, in a group of five, six, or seven on each side; none in <i>Ithone</i>.</p> <p>Antennæ — simple, setiform, few- to many-segmented.</p> <p>Labrum — generally reduced, often only a slender margin of the clypeus.</p> <p>Clypeus — broad triangular plate.</p> <p>Mandibles — variable, sharp, short or long, straight or curved, simple or toothed; grooved on ventral side and combined with maxillæ to form two sucking tubes.</p> <p>Maxillæ — reduced to separate blades usually similar in size and form to the mandibles, under which they fit to close the mandibular grooves.</p> <p>Labrum — reduced, may be longitudinally divided.</p> <p>Palpi — usually shorter than antennæ, three- to seven-segmented.</p> <p>Neck — connects head and prothorax and is considered as part of latter; short and membranous or long and tube-like, often conspicuous.</p> <p>Thorax — <i>Prothorax</i> divided into three parts.</p> <p><i>Meso-</i> and <i>metathorax</i> similar, normal.</p> <p>Legs — uniform; <i>coxae</i> — large and widely separated; <i>trochanters</i> — small; <i>femora</i> — equal to or smaller than tibiae; <i>tibiae</i> — longest segments; <i>tarsi</i> — one-segmented (tibia and tarsus fused in all legs of <i>Ithone</i> and the hind legs of the myrmeleonids and ascalaphids); <i>claws</i> — usually two (one in <i>SISYRIDÆ</i>); <i>empodium</i> — present in</p>	<p>Digestive System.</p> <p>Mouth — no true mouth exists; the liquid food enters through two channels formed by the mandibles and maxillæ. Food sucked into pharynx by pharyngeal pump.</p> <p>Œsophagus — either constricts or has a valve.</p> <p>Crop — thin-walled, large, occupies much of the thorax.</p> <p>Mid-intestine — a large, blind sac occupying anterior half of the abdomen.</p> <p>Malpighian tubes — eight (six in <i>CONIOPTERYGIDÆ</i>) arising from extremity of mid-intestine and extending forwards and backwards. May secrete silk towards end of larval period.</p> <p>Hind intestine closed to passage of food; a fold envelops apices of Malpighian tubes and enables contents of latter to enter silk reservoir.</p> <p>Silk reservoir — thin-walled sac which supplies fluid for spinning silk for cocoon and other purposes.</p> <p>Rectum — narrow, leads to anus; anal papilla extrudes as spinneret for spinning the cocoons.</p> <p>Salivary glands — empty into the tubes at the bases of the jaws and extend along sides of œsophagus.</p> <p>Circulatory System.</p> <p>Normal. The dorsal vessel narrows in the prothorax to form an aorta.</p> <p>Respiratory System.</p> <p>Spiracles — one pair prothoracic. Eight pairs abdominal on first eight segments. Two main longitudinal tracheal trunks. Tracheal gills in <i>SISYRIDÆ</i>.</p> <p>Nervous System.</p> <p><i>Supra-</i> and <i>sub-œsophageal</i> ganglia within the head.</p> <p>Three thoracic and eight abdominal ganglia connected by a pair of commissures.</p>

* Dolichasters are funnel-shaped organs arising from the centers of chitinous papillæ of the integument. A transverse section reveals a star-shaped structure. They occur in *Psychopsis* and the myrmeleontid groups.

IMPORTANT ANATOMICAL CHARACTERS — LARVÆ — *Continued*

<i>External</i>	<i>Internal</i>
many families, trumpet-shaped, knobbed, or pad-like. <i>Spiracles</i> — one pair on posterior area of prothorax. <i>Abdomen</i> — 10-segmented, last two may be hidden; smooth or tuberculate; with gills in SISYRIDÆ. <i>Spiracles</i> — a pair each on segments I to VIII inclusive.	

The adults are for the most part delicate and fragile and, though they have well-developed wings, most of them are poor and erratic fliers. The members of the families ASCALAPHIDÆ and STILBOPTERYGIDÆ are rapid on the wing and fly in a more or less straight line.

The members vary in size from the minute dusty wings, which have a wing expanse varying from 3–10 mm., to the large showy moth lacewings with an expanse of from 30–70 mm., and the ant lions which have very long, slender bodies like those of dragonflies. The various peculiarities of the order are more appropriately discussed under the different families.

According to Tillyard (1926) *Permithone belmontensis* Till., from the Upper Permian of Belmont, Australia, is the oldest known member of the order. ¹ The ITHONIDÆ, probably the BEROOTHIDÆ, and allied families are descended from it. The extinct family PROHEMEROBIIIDÆ and representatives of the PSYCHOPSIDÆ are represented in the Upper Trias of Ipswich, Australia. The former is also abundantly represented in the Lias and the Upper Jurassic of Europe as are also the allied CALLIGRAMMATIDÆ and forms similar to the CHRYSOPIDÆ and the NYMPHIDÆ.

The members constitute rather a small order consisting of some 40 families, some 350 genera, and about 4,000 species. They are distributed throughout the entire world and are met with in practically every locality where plant and animal life exist. As a whole the order is to be considered as beneficial since the larvæ, and adults in some families, are voracious predators upon many types of small destructive insects and mites, and also feed upon any small insects they can overcome.

The pupæ are always free, enclosed in a silken cocoon, curved with the head and tip of abdomen near each other, and with all the appendages visible. Prior to emergence they become quite active and sever the cocoon with the well-developed mandibles or cut out a disk to escape before the adult stage is attained.

There seems to be no agreement among taxonomists as to the proper group-

¹Suborder PLANIPENNA of the order NEUROPTERA according to some authors. According to Tillyard the other suborder is MECOPTERA.

ing of orders. I am using a modification of that of Handlirsch (1906) and of Stitz (1931).

Family CONIOPTERYGIDÆ¹ Enderlein 1905 (Con'i-op'te-ryg'i-dæ, from the Greek *κόνιος*, dusty, + *πτερά*, wings; referring to the powdery wax which covers the wings and body). German, Staubhaften. French, Conioptéry-gidés. Dustywing, Coniopterygids.

The adults are very small to minute insects usually partly or wholly covered with fine whitish powdery wax which gives them their common name. The

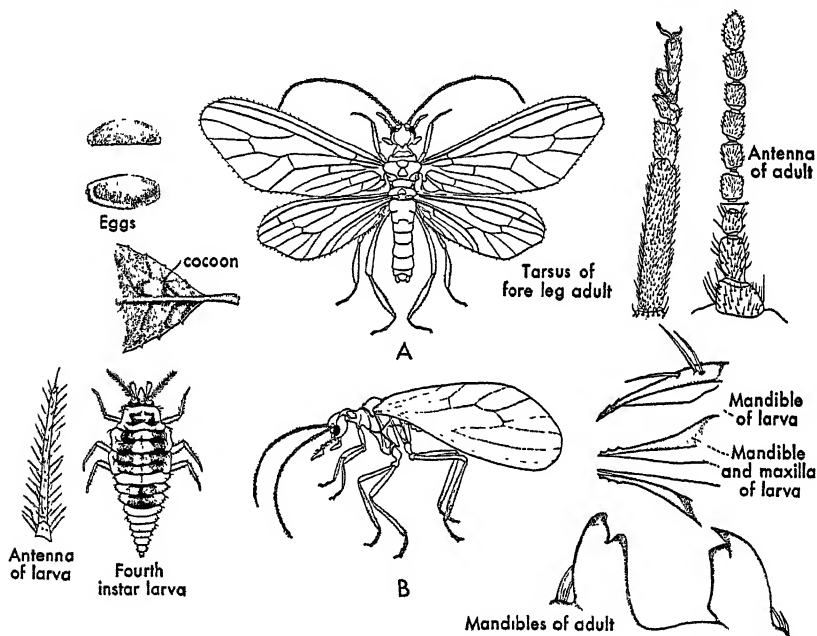


FIG. 131. The coniopterygid, *Parasemidalis flaviceps* Banks. The adults and parts of the larvæ are covered with a white powdery wax. (Redrawn from H. Rustad, 1932.)

wax is secreted by hypodermal cells similar to those of the homopterous family COCCIDÆ and serves a similar purpose. The imagines are very fragile and are the smallest members of the order NEUROPTERA, having a wing expanse of only 3–10 mm. The antennæ are long, filiform, and with 16 to 43 bead-like segments; eyes large, ocelli absent; wings similar or the hind pair much reduced, veins relatively few as compared with other members of the order. The adults are quite active and appear to be mainly arboreal in habits. They occur particularly on coniferous trees, but many species frequent other kinds of trees, shrubs, and smaller plants.

¹ This family appears to be worthy of the rank of a separate order.

The eggs are white, yellow, orange, or pink and are oval or somewhat flattened with a conical micropylar knob. The surface has a network of polygonal depressions. The eggs are often attached to the various parts of the leaves in close proximity to the host. They are so small as to be very difficult to find without the aid of a lens or microscope.

The larvæ are wide anteriorly and taper to a point posteriorly. They are quite smooth, with large thorax and small abdomen. The head is small; five simple eyes are on each side; antennæ five-segmented; the labrum covers the mouth parts; the mandibles and maxillæ are short or quite long, straight, and needle-like; the labial palpi are clavate and three-segmented. The legs are long, hairy, and terminate in a pair of slightly curved claws and a pad-like empodium. The larvæ are hunters that prey upon small living insects such as white flies or mealy wings (which they simulate with their waxy covering), aphids, coccids, and other homopterous species, and orchard mites or red spiders and other mites. When mature they spin a thin, disk-like double cocoon which often appears like a transparent scale enclosing the occupant.

Because of their small size these insects are not so well known as most of the larger members of the order. They are never very abundant. There are only about 12 genera and approximately 50 known species, occurring in various parts of the world.

Coniopteryx tineiformis Curtis, *C. borealis* Tjeder, and *C. pygmaea* Enderlein are common to western Europe. The last named is one of the smallest members of the order, having a wing expanse of only 5.5 mm. *C. angustus* Banks and *C. vicina* Hagen occur in North America, and *C. pulverulenta* Endl. inhabits Japan. *Conwentzia psociformis* Curtis and *C. pineticola* Endl. are European, and *C. hageni* Banks is North American. *Semidalis curtisiana* Endl. and *S. aleyrodiformis* (Stephens) are common representatives in Europe, while *S. albata* Endl. occurs in Japan and *S. kolbei* Endl. in Chile. *Aleuropteryx loewei* Klapálek is European, and *A. walshi* Banks is North American. *Malacomyza fitchi* Banks, *M. farinosa* Banks, and *M. westwoodi* Fitch occur in North America. *Parasemidalis annæ* Endl. is European, *P. farinosa* McLachlan is Australian, and *P. flaviceps* Banks is common in California on shrubs infested with white flies. *Spiloconis maculata* Endl., with a wing expanse of 10 mm., is the largest species in Australia.

Family ITHONIDÆ¹ Tillyard 1919 (Ith-on'i-dæ, from the Greek Ἰθωνία, the goddess Athene). The Moth Lacewings.

This archaic family is closely related to the order MEGALOPTERA. The adults are large showy moth-like species with a wing expanse of 30-70 mm. and are among the largest members of the order. The head is small and set close into the prothorax; the antennæ long, filiform, and from 40- to 50-segmented; the males have pincer-like genital appendages, and the females, according to Tillyard (1926), lay their eggs in the sand by means of a sand plough. The adults are very active runners and quickly conceal themselves if disturbed.

¹ Newman erected the family ITHONESIDÆ in 1853, but it has not been accepted.

The eggs, as observed by Withycombe (1924), are large, oval, smooth, with a disk-like micropylar knob, creamy white in color, and covered with an adhesive fluid to which particles of the soil adhere.

The larvæ, described by Withycombe (1924) and Tillyard (1926), are eruciform and curved and are similar in appearance to the white grubs of scarabæid beetles. They have small heads, no eyes, and microtrichia and macrotrichia over the surface. The legs are strong and adapted to digging in the sand and soil. The tibiæ and tarsi of all legs are fused into one segment. The short, straight, piercing mouth parts are unusual because of the great enlargement of the maxillæ. There are one pair of prothoracic and eight pairs of abdominal spiracles. An odor similar to citronella, the common mosquito repellent, is emitted. The larvæ prey upon white grubs, which they closely resemble, as well as upon other soil-inhabiting insects, and are therefore considered beneficial. They pass through five instars.

This very small family is composed of at least five genera and about 13 species. Three genera, including *Ithone* Newman, and six species occur in Australia. A genus and single species, *Oliarces clara* Banks, inhabits California, and the genus *Rapisma* the Himalaya Mountains of Asia.

Family SISYRIDÆ Handlirsch 1906 (Sis-yr'i-dæ, from the Greek *σίσυρα*, fur, goat's hair; referring to the hirsute covering of the body and wings).
Spongilla Flies.

The spongilla flies, as the adults are called, are small species measuring 6–8 mm. in length and are usually fuscous or brownish in color, with a few long hairs on the legs and body. The compound eyes are large, ocelli absent, the antennæ about half as long as the fore wings, the mandibles and maxillæ setiform, labial palpi absent, and the claws single. The wing venation is simple with few cross veins.

The eggs of *Sisyra* are very small, elongated, and somewhat resemble those of *Hemerobius*. They are laid in masses on objects standing in or overhanging fresh water and may be covered with a silken web.

The larvæ differ from most of the other species in the order in being aquatic and in feeding upon living fresh-water sponges of the genera *Spongilla*, *Ephydatia*, and probably others. They may also be found on bryozoans and algæ. They may be greenish or brownish in color, with two rows of dorsal and two rows of long lateral groups of hairs arising from body tubercles and seven pairs of segmented abdominal gills. The mouth parts, long, needle-like, and slightly recurved apically, serve well to pierce the bodies of the sponges upon which they subsist. When mature the larvæ seek the shore above the water line and pupate in an oval loose double cocoon in the soil or under stones and debris.

The family consists of some six genera and 20 species distributed throughout the continents of Europe, Asia, Africa, Australia, North America, and South America. The dominant genus, *Sisyra* Burmeister, is Holarctic, and *Climacia* McLachlan is Nearctic. There are at least four species in Europe: *Sisyra fus-*

cata (Fab.), *S. dahlii* McL., *S. terminalis* Curtis, and *S. jullandica* E. Petersen. *S. brunneus* Banks is the best known species in Australia, *S. nikkoana* Navás in Japan, and *S. vicaria* Walker in North America. It is well to call attention to the fact that these insects are nowhere very abundant and are therefore rarely met with either in insect collections or in books.

Family OSMYLIDÆ Brauer 1868 (Os-my'li-dæ, from the Greek *ὀσμή*, a smell or odor; referring perhaps to odors of some species). Osmylid Flies.

Medium to large, slender, beautiful species with marked wings. The fore wings are somewhat larger than the hind wings, the discal areas have very many cross veins, and the marginal area is without cross veins but with many forked veinlets. The head is wider than long, the antennæ filiform and shorter than the wings; three ocelli near the frons; the claws many toothed (four or five or 10-12). The body and legs are clothed with a few long hairs. It comprises a widespread group of about 20 genera and 50 species which do not occur in North America, but are known in Europe, Asia, Africa, South America, and Australia. The most important genera are *Osmylus* Latr., *Spilosmylus* Kolbe, *Kalosmylus* Krüger, *Rhipidosmylus* Krüger, and *Stenosmylus* McLachlan.

Osmylus chrysops (Linn.) with a wing expanse of 37-52 mm. is the largest neuropteran in Great Britain. The larvæ are long, slender, and dark, live under stones, leaves, moss, and debris near the water, and have long, nearly straight, needle-like mandibles and maxillæ. They feed upon maggots and on larvæ of other insects living in their habitat. Pupation occurs in a soft cocoon. Their elongate-oval eggs are laid near the water.

Climacia areolaris Hagen of the Canary Islands has a wing expanse of only 7 mm.

Family HEMEROBIIDÆ Westwood, 1840 (Hem'er-o-bi'i-dæ, from the Greek *ἡμέρα*, day, + *βίος*, life; meaning living for a day, a false conception concerning the true biology of these insects). German, Blattlauslöwen. French, Hemerobiidés. Hemerobiids, Brown Lacewings, Aphis Wolves.

These small lacewings are usually brownish, and often with golden and other iridescent colors; ocelli absent; antennæ long and moniliform; wings similar, sometimes with irregular margins at tips, brown, hairy, with many small cells, the costal area being crossed by many numerous branched veinlets, and without a pterostigma. The adults are fragile in appearance, slow-crawling, and have an erratic flight. They occur on nearly all types of vegetation and are often taken at lights by night.

The eggs are regularly elongate-oval and 0.5-1.0 mm. long, the surface smooth, pitted, or pebbled and with micropylar knob. They are deposited singly or in groups, attached by their sides.

The larvæ are similar to those of the CHRYSOPIDÆ but are smooth, without tubercles, and have only fine hairs. The mandibles and maxillæ are curved but short. There are two claws and, in the first instar only, a trumpet-shaped

empodium, which becomes pad-like and greatly reduced in the later instars. They are predacious in habit and stalk their prey on the surface of the ground or more often on trees and smaller plants. They are called aphid wolves from their habits of feeding upon aphids, but they also devour scale insects, especially mealybugs, white flies, psyllids, members of other homopterous groups, and small insects in general as well as mites. Their general habits and movements are also very much like those of the chrysopids. Pupation takes place in a thin,

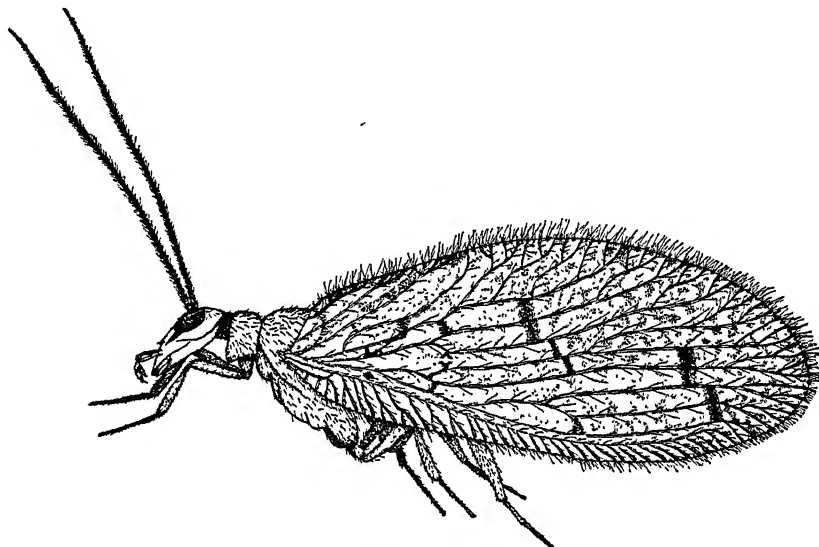


FIG. 132. The brown lacewing, *Sympherobius angustatus* (Banks).

often lace-like, oval cocoon hidden in crevices or under scales of bark, in the litter on the ground, or even in the soil.

The family is composed of at least 25 genera and 220 species distributed throughout the entire world and is especially well represented in the north temperate regions.

Hemerobius humulinus Linn., and *H. marginatus* Stephens are common both to Europe and North America. *H. conjunctus* Fitch, *H. hyalinatus* Fitch, *H. moestus* Banks, and *H. pacificus* Banks are widespread in North America. *H. pini* Leach, *Micromus angulatus* Stephens, *M. variegatus* Fab., and *M. paganus* (Linn.) are also European. The latter species has a wing expanse of 18–27 mm. *M. angulatus* Stephens, *M. posticus* Banks, and *M. variolosus* Hagen are North American, and *M. tasmaniae* Walker is Tasmanian. The genus *Drepanopteryx* Leach is European and Asiatic, *Boriomyia* Banks occurs in North America and New Zealand, and *Megalomus* Rambur in North America and Australia. The family is well represented in Japan by the genera *Hemerobius*, *Micromus*, *Eumicromus*, *Ningula* (*Ninga*), and *Drepanopteryx*.

Family SYMPHEROBIIDÆ Brues and Melander 1932 (Sym'phe-ro-bi'i-dæ, from the Greek *συμφέρον*, advantage, + *bios*, life). Sympherobiids, Brown Lacewings.

A very small family closely related to the preceding family and distinguished by differences in wing venation, there being apparently two radial sectors (R_{2+3} and R_{4+5}) in the fore wings.

The dominant genus, *Symphorobius* Banks, is represented by more than 10 species in North America. *S. angustatus* Banks is one of the commonest species. The adults are brown, hairy, and 6 mm. long. The eggs are white and oval and are laid singly. The larvæ are spindle-shaped, dull slate-colored with brownish legs and mouth parts, with few hairs on the body, and are from 5–6 mm. long when fully matured. The head is small, the antennæ short and three-segmented, the labial palpi three-segmented, the mandibles and maxillæ short, stout, and slightly incurved. The larvæ crawl rather slowly but keep the head in a rapid side-to-side motion in search of prey which consists chiefly of mealybugs and other small insects. Pupation occurs in an oval, loose, thick, white cocoon which is to be found at any secluded place near the food supply.

In western Europe *S. pygmaeus* (Rambur) (*S. elegans* Stephens) and *S. pelucidus* Walker are the only common species.

Psectra diptera Burmeister also occurs in North America and the genus *Carobius* Banks in Australia.

Family CHRYSOPIDÆ Hagen 1866 (Chrys-op'i-dæ, from the Greek *χρῖσος*, golden, + *ὄψ*, eye; referring to the golden luster of the eyes of the living adults). German, Goldaugen, Florfliegen. French, Chrysophes. Golden Eyes, Green Lacewings, Stink Flies.

The adults are small to medium-sized, (wing expanse 31–65 mm.) fragile, yellowish, gray, or green insects which are among the most beautiful objects in nature. Markings of black, brown, orange, red, pink, and yellow are present on some species, and the wings may be wholly transparent or gray in color. The head is small, and the antennæ are filiform and often longer than the body. The brilliant and iridescent golden compound eyes are large and widely separated, and there are no ocelli present. The mouth parts are normal for the order, the labrum being slightly emarginate or entire. The wings are similar in shape and structure, the hind pair being somewhat smaller than the fore wings; they are usually transparent, but some species have clouded areas; the tips are rounded; and the costal cell has less than 30 cross veins.

The imagoes of certain species have glands which emit an offensive odor, responsible for the common name, stink flies, but I have not noticed this in our western American forms. The flight is weak, erratic, and usually short, but *Chrysopa dorsalis* Burmeister of Europe is said to be a strong and rapid flier. They are frequently attracted to lights at night (considerable numbers may be collected around a light). It is known that the adults prey upon small insects and mites as the larvæ do, but in the open they never appear to be extensively engaged in seeking prey but seem more concerned in finding suitable places for

laying their white or pale-green eggs on long slender stalks, which often bend under the weight of the burdens. The eggs may be laid singly or in groups of 20 or more on plants or other objects. The European species, *Chrysopa flava*

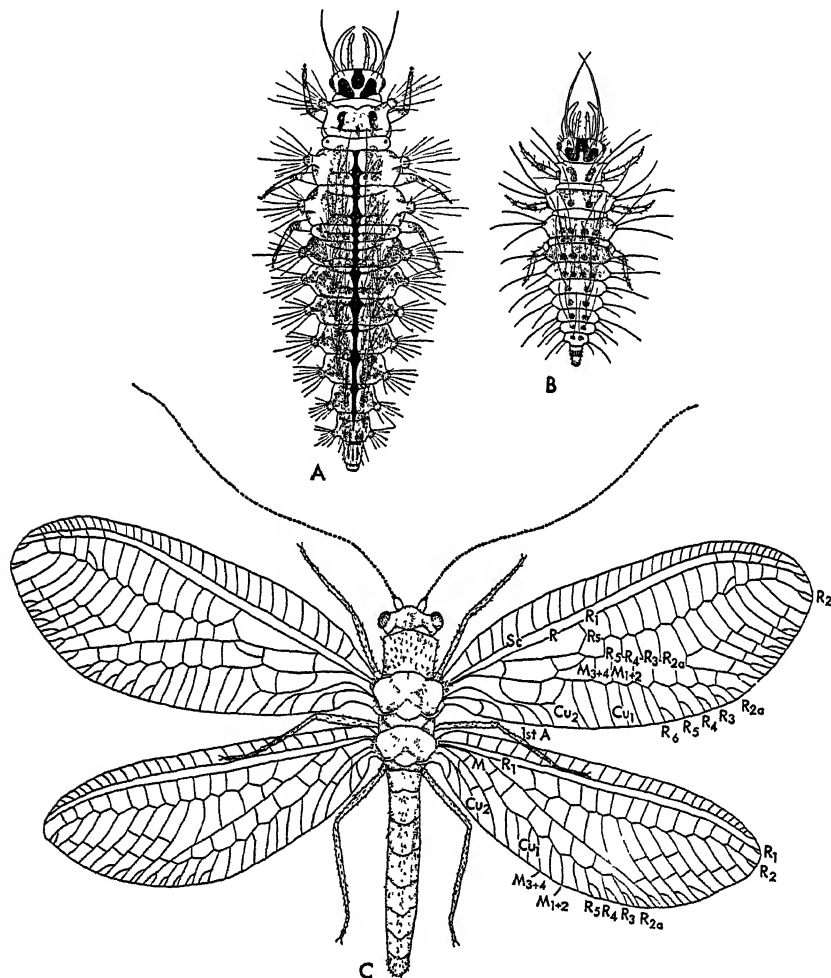


FIG. 133. CHRYSOPIDÆ. A, mature and B, 1st instar larvæ of the North American golden eye or green lacewing, *Chrysopa oculata* Say (after Smith, 1922); C, adult European pearly lacewing, *Chrysopa perla* (Linn.).

(Scopoli), joins the stalks of many eggs into a common bundle from which the eggs radiate at the top.

Upon emergence from the eggs, the larvæ rest awhile on the swinging shells and then descend to take up a roving hunter's life. For this pursuit they are

admirably endowed with a tough, elastic, and sometimes spiny skin; short, stout legs terminating in a pair of strong claws; and a long trumpet-shaped empodium; long, sharp, sickle-shaped mandibles and maxillæ; an insatiable appetite and a fearless instinct. They stalk their prey, chiefly living aphids, from which they get the name "aphis lions," but they also devour leafhoppers, psyllids, scale insects, mites, and young spiders and eggs and small larvæ of moths, of butterflies, of beetles, and of sawflies; — in fact almost any minute animal that can be dispatched with their pincer-like jaws. The body of the victim is pierced and the juices quickly extracted.

In some species, for instance *Chrysopa lineaticornis* Fitch of North America and *C. ciliata* Wesmael of Europe, the larvæ are protected by a disk-like shield



FIG. 134. Eggs of the California green lacewing, *Chrysopa californica* Coquillett. (From *Insects of Western North America*.)

of trash or debris which covers the dorsum, and these are known as trash or packet carriers. Because they destroy so many insects injurious to plant life and particularly to food crops and ornamentals they are ranked as highly beneficial to mankind. When fully grown, the larvæ seek secluded places under scaly bark of trees or elsewhere and spin oval or spherical, tough, closely woven, smooth cocoons, which are pearl-like and often mistaken for insect eggs.

The CHRYSOPIDÆ comprise a large family of some 25 genera and 420 species distributed chiefly throughout the temperate regions of the world and occur on all the large land masses except New Zealand. The dominant genus, *Chrysopa* Leach, is cosmopolitan and is very well known wherever it occurs. In Europe there are at least 15 species (two genera and 14 species inhabit Great Britain) including the common *C. vulgaris* (Linn.), *C. perla* (Linn.), *C. vittata* Wesmael, *C. ciliata* Wesmael, *C. carnea* Stephens, *C. dorsalis* Burmeister, and *C. flava* (Scopoli). Of the 12 or more North American species, *C. oculata* Say, *C. interrupta* Schneider, *C. plorabunda* Fitch, and *C. nigricornis* Burm. are important east of the Rocky Mountains and *C. rufilabris* Burm., *C. coloradensis* Banks, and *C. californica* Coquillett are common in the West. In Australia

there are no less than 28 species belonging to the family. *Chrysopa* is the chief genus, with *C. notata* Walker the commonest species. *C. flava* (Scop.) also occurs there.

Nothochrysa insignis Walker is one of the largest species, and *Dictyochrysa fulva* E. Petersen is a distinct Australian species with a regular network of similar wing cells. Japan is rich in members of this important family, having at least five genera and many species including the European *Chrysopa vittata* Wesmæel.

The beautiful South American *Loyola crassus* Navás with a wing expanse of 65 mm. is probably the largest species in the family, and *Notiobiella unita* Banks, of Australia with an expanse of only 8 mm. is one of the smallest.

Other important genera are *Allochrysa* Banks, *Meleoma* Fitch, *Leucochrysa* McLachlan, and *Eremochrysa* Banks.

Family BERTHIDÆ Handlirsch 1908 (Ber-oth'i-dæ, from the Greek *βερβή*, a nymph). Beaded Lacewings.

The adults are small and slender with long filiform antennæ and without ocelli; the wings are variable in shape, hairy, and often with peculiar seed-like scales attached to the important veins of the females. The eggs of *Spermophorella* are elongate and raised on stalks, thus resembling those of *Chrysopa*. They usually occur in groups in the larval habitat. The larvæ are thysanuriform, with short straight mandibles and maxillæ. Those of *Spermophorella disseminata* Tillyard live in sandstone caves in New South Wales, Australia, and are suspected of preying upon caterpillars which live on the lichens in and about the caves. As a matter of fact, little or nothing is known concerning their biology.

This small family consists of some 10 genera and 30 species which are scattered in Asia, Africa, Australia, New Zealand, and North America. Eight species live in Australia and one in New Zealand. The genus *Bertha* Walker is Indo-Malaysian, *Cyclobertha* Tillyard and *Spermophorella* Tillyard are Australian, and *Lomamyia* Banks is North American. The latter has two species, *L. flavicornis* Walker, in the eastern states and *L. texana* Banks, in the western states.

Family DILARIDÆ Handlirsch 1906 (Di-lar'i-dæ, from the Greek *δῖς*, doubly, + *λαρός*, pleasant to the eye). Pleasing Lacewings.

Small insects in which the veins and cross veins of the wings have numerous branches around the margins. The three ocelli are tuberculate and prominent. The antennæ of the males are pectinate, and the females have an exserted ovipositor.

This is a small family of some six genera and 30 species occurring in Europe, Asia, Africa, North America, and South America. The most important genera are *Dilar* Rambur, *Lidar* Navás, and *Nepal* Navás. *Dilar americana* McLachlan is North American, and *D. japonica* McLachlan is Japanese.

Family POLYSTÆCHOTIDÆ Handlirsch 1906 (Pol'y-stæ-cho't'i-dæ, from the Greek πολὺς, many, + στοῖχος, row: referring to the arrangement of the wing veinlets). Large Lacewings.

The adults are medium-sized to large insects with a wing expanse of 40–75 mm. The wings are long; the discal area has many forked veinlets, and the hind pair is without an anal field. The antennæ are short and setiform, and the female has no ovipositor.

This small family has but one genus, *Polystæchotes* Burmeister. Two species, *P. punctatus* (Fab.) and *P. vittatus* Say, are North American. The former occurs throughout much of the continent from the Atlantic Ocean to the Pacific, and

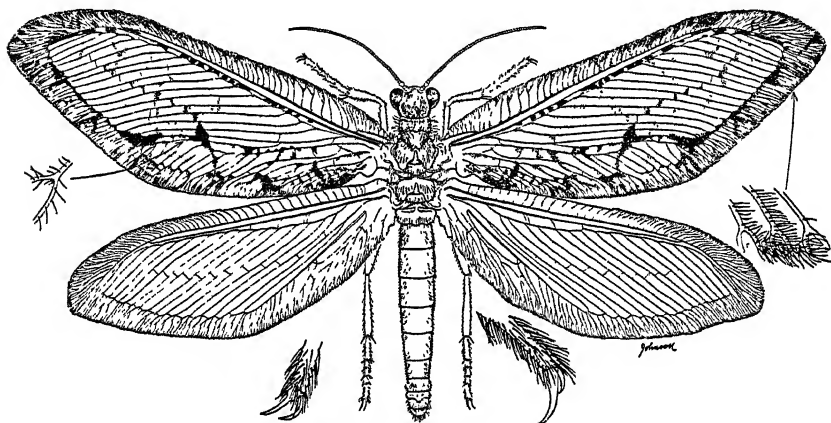


FIG. 135. *Polystæchotes punctatus* (Fab.), a common North American species.

the latter is an eastern species. The larvæ of *P. punctatus* has short, sharp, sickle-shaped mandibles, and the maxillæ are stout and blunt. The labial palpi are five-segmented, the tarsal claws are simple and only slightly curved, and the knobbed empodium is twice as long as the claws. Withycombe (1924) believes the form of the larva to be more like that of the order MEGALOPTERA than that of any other larva in the order NEUROPTERA. Welch (1914), who hatched larvæ from eggs laid in confinement, thought they might be terrestrial and arboreal, but Withycombe (1924) thinks from the shape of the claws they can hardly be arboreal.

Polystæchotes gazullæ Navás occurs in Chile.

Family APOCHRYSIDÆ Brues and Melander 1910 (Apo-chrys'i-dæ, from the Greek ἀπό, from, off, + χρυσός, gold; it being a group taken from the family CHRYSOPIDÆ). Fragile Lacewings.

A very small family recently separated from the CHRYSOPIDÆ and restricted to Australia, Papua, East Indies, and Asia. The adults are very fragile with distinctly larger hind wings, filiform antennæ, and a costal area having

more than 40 cross veins. *Apochrysa* occurs in Papua and Japan and *Oligochrysa gracilis* E. Petersen in eastern Australia.

Family PSYCHOPSIDÆ Handlirsch 1908 (Psy-chop'si-dæ, from the Greek $\Psi\upsilon\chi\acute{\eta}$, butterfly, + $\psi\psi$, appearance; referring to the beautiful butterfly-like adults). Silky Lacewings.

The adults are large, beautiful, moth-like lacewings of striking and often contrasting colors. The head is depressed and covered by the bases of the fore wings, the antennæ are short and setiform, and the wings are broad with the costal areas greatly enlarged and separated by three parallel veins which do not extend to the tips but distinctly mark the species. They are crepuscular and nocturnal. The eggs of *Psychopsis* are oval, pale yellowish-green, with a micropylar knob, and are attached by their sides, one or more at a place. The larvæ are elongated and flat, the grayish color due to the whitish pubescence. The jaws are large and sickle-like. Australian species live under the shaggy bark of certain eucalyptus trees and are predacious upon insects that are available. Pupation occurs in a pearl-like spherical cocoon similar to that of the CHRY-SOPIDÆ but larger. Several of the Australian species are very beautiful (see Tillyard, 1926).

This family arose at least as early as Triassic in Australia in particular, but also in India, China, and Africa.

The family is composed of some eight genera and 20 species occurring in Australia, Asia, and South Africa. *Psychopsis* Newman is the dominant genus.

Family NYMPHIDÆ Tillyard 1926 (Nymph'i-dæ, from the Greek $\nu\mu\phi\eta$, nymph). Slender Lacewings.

The adults are slender, with long, filiform antennæ and long, narrow, many-veined wings whose costal areas have many cross veins. This small family is composed of three genera and six species, all occurring in Australia, Norfolk Islands, and Papua. The best known Australian species is *Nymphes myrmeleonides* Leach, which is orange-brown and has a pungent odor. The eggs are supported on long slender stalks in places of concealment under shaggy bark and in debris where the larvæ, which are similar to ant lions, ambush their living prey. The mandibles of the larvæ are sickle-shaped and have a single internal tooth. The cocoon is spherical, brownish, and attached by a stout thread.

Family NEMOPTERIDÆ Burmeister 1839 (Ne'mop-ter'i-dæ, from the Greek $\nu\eta\mu\alpha$, thread, + $\pi\tau\epsilon\rho\acute{\alpha}$, wings; referring to the very slender ribbon-like hind wings). Spoon-winged and Thread-winged Lacewings, Nemopterid Flies.

The members of this family are a very unusual and highly specialized group in which the hind wings are long and ribbon- or shaft-like, sometimes with leaf- or spoon-like enlargements near the apices, and two to three times as long as the body. The adults are delicate lacewings with elongated and snout-like head. They are crepuscular and frequent caves and buildings in desert or semiarid

regions. According to Withycombe (1924), the eggs of *Nemoptera bipennis* Illiger, the common European species, are nearly spherical, verrucose, with pedicellate micropylar knob, and those of *Croce* are oval, wholly smooth, and greenish in color. The latter are deposited singly in the dust.

The larvæ of this family differ much among themselves and greatly from other members of the NEUROPTERA. The head is large, with long filiform antennæ, curved mandibles, and with or without a distinct neck. There are two curved claws, but no empodium. Pupation occurs in a cocoon of silk and debris. In the pupa the hind wings may be crossed and coiled over the abdomen.

The family consists of about 12 genera and 50 species occurring chiefly in southern Europe, Asia, Africa, Australia, and South America. One species occurs in northern Chile.

In *Croce filipennis* Westwood of India the hind wings of the adults are feather-like and more than three times as long as the body. The larvæ have large heads, with toothed, sickle-shaped jaws, and a slender neck nearly as long as the head. The larva of the remarkable *Pterocroce storeyi* Withycombe of Egypt has a cylindrical neck as long as the body, and the neck of the larva of *Nina joppana* of Palestine is almost as long. These two species live in the dust of caves and rock ledges and feed upon the larvæ of dermestids and other available insects.

Family MYRMELEONTIDÆ¹ Burmeister 1829 (Myr-me'le-on'ti-dæ, from the Greek *μύρμηξ*, ant, + *λέων*, lion; referring to the ant-devouring habits of the larvæ). German, Ameisenjungfern. French, Fourmilions. Ant Lions, Ant Lion Flies, Myrmeneontids, Doodle Bugs.

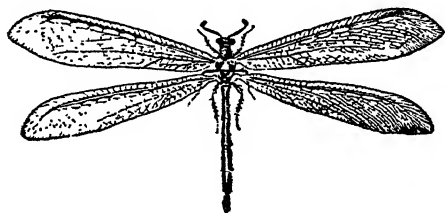
The adults of these well-known insects somewhat superficially resemble dragonflies and damselflies because of their long slender wings and bodies. They are usually partly pubescent, with short clubbed or fluted antennæ, and they frequently have spotted wings which are similar in size, shape, and venation, have regular oblong cells in the apical spaces, and are without a distinct pterostigmal area. They usually fly at dusk but may be taken on the wing on dull, cloudy days.

The larvæ are perhaps better known than the adults and are called "doodle bugs." They are also given the name "ant lions" because of their predatory habits on ants. They have a large plump hairy body, small head equipped with large, three-toothed, sickle-shaped, snapping jaws, and strong legs which are peculiar in that the tibia and tarsus of the hind legs are fused together. They are patient ambuscaders, lying buried at the bottom of a sandy funnel-shaped lurking-hole or pit, awaiting the victims that chance to stumble over the sliding brink. These pits vary in size with the age of the occupant and are usually found scattered or in groups of several to a great many. Favorite locations are exposed areas on the protected sides of stones, ledges, trees, stumps, and other

¹ The name MYRMELEONIDÆ was not erected by Stephens until 1836. It is most commonly used as the family designation.

objects in sandy or dusty places. In California they are particularly abundant in the hilly and mountainous regions.

The larvæ of some species do not make pits but simply hide under sand, dust, leaves, stones, and debris. Larvæ of *Myrmeleon contractus* of Bengal inhabit mud-covered tree trunks and prey on ants. Much has been written as to the habits of these interesting insects, and nearly every school boy and girl is familiar with many of their antics. They destroy great numbers of ants but do not appear to produce any appreciable effect in the reduction of these pestiferous hosts, even where the ant lions are most abundant. When mature,



the larva constructs a globular cocoon and pupates in the sand or other place of concealment. Their nearly spherical eggs have two micropylar areas and are laid in the sand or other habitat of the larvæ.

This is the dominant family of the order and has no less than 40 genera and 650 species which are chiefly tropical and subtropical, though many are also temperate. They occur in Europe, Asia, Africa, Australia, New Zealand, North America, and South America. In Europe there are five common genera and 14 or more well-known species, but singularly enough the family is not represented in Great Britain. One of the important European species is *Myrmeleon formicarius* Linn. which occurs also in Japan. In North America there are at least 11 genera and a great many species. *Brachynemurus* Hagen is the predominating genus, with a large *Myrmeleon* Linn. is second with

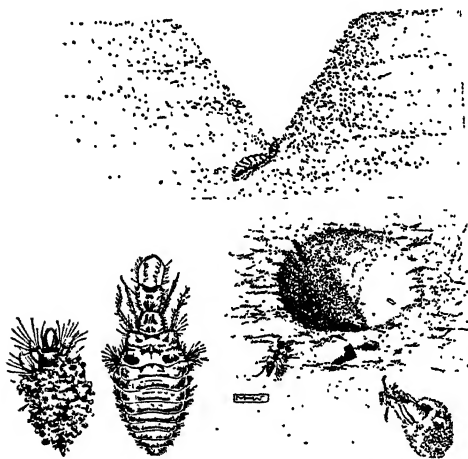


FIG. 136. An ant lion, *Hesperoleon* sp. Adult, sand pits, larvæ, and pupa. (Partly from Kellogg, *American Insects*, Henry Holt and Company.)

number of species throughout the country. less than half as many species. Nine other each. A common North American species is *Myrmeleon immaculatus* De-Geer.

Australia has 36 genera and 95 species and New Zealand two species. The dominant genera are *Glenoleon* Banks and *Formicaleo* Leach, each with some 12 species. *Periclystus circuire* Walker and *P. laceratus* Gerst. have a wing expanse of 4 in. while the huge *Acanthaclisis fulva* E. P. and *A. peterseni* Till.

have an expanse of 7 in. The larvæ of the genera *Myrmeleon* and *Callistoleon* make cone-shaped pits in the sand.

The commonest South African genus is *Palpares* Rambur which includes very handsome species of large size. *P. voeltzhowi* Kolbe, one of the largest members of the order, has a body length of 63 mm. and a wing expanse of 157 mm.

Family STILBOPTERYGIDÆ Tillyard 1926 (Stil-bop-te-ryg'i-dæ, from the Greek *στίλβειν*, shine, + *πτερά*, wings; referring to the shining wings). Shiny Wings.

The adults are large, high, swift fliers, and on the wing resemble dragonflies except that they fly only straight ahead and are not versatile in backing up, darting, and dodging like the latter. They have short, knobbed antennæ, very large eyes, and shining wings and abdomen. They fly at dusk. The large black spiny larvæ live in vegetable refuse and prey upon small living insects and other animals.

The family is represented in Australia by the genus *Stilbopteryx* Newman with three species and in South America by *Albardia* Weele.

Family ASCALAPHIDÆ Schneider 1845 (As'ca-laph'i-dæ, from the Greek *ἀσκάλαφος*, an owl; because of the nocturnal habits of some species?). German, Schmetterlingshaften. French, Ascalaphidés. Ascalaphus Flies, Owl Flies.

In the adults the heads are covered with long fine hairs which are shorter on the rest of the body. The antennæ are filiform, clavate, or knobbed and as long

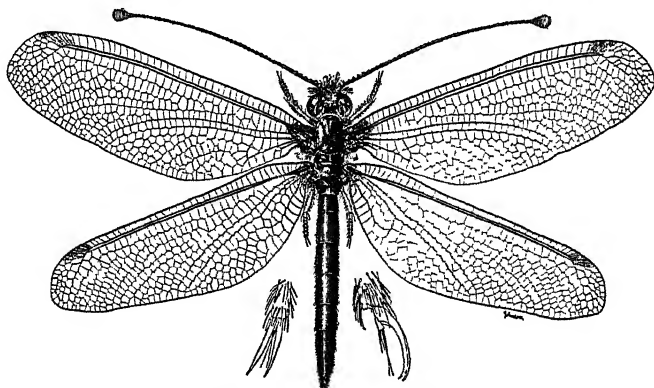


FIG. 137. An ascalaphus fly from Formosa with claws much enlarged.

or longer than the fore wings. The upper portion of each of the large eyes may overlap the lower as if divided by a groove. The wings are often partially pigmented, the hind pair shorter and much wider than the fore wings, many-veined, the apical areas with irregular cells and a small pterostigma. The rather large dragonfly-like species attain a length of 40–50 mm. Some species are

rapid fliers but most of them are slow and erratic. At rest, the wings are slightly drooped or partly closed in a characteristic pose. They capture their prey on the wing either by day or by night. The males have a pair of pincer-like anal claspers. Some species have a strong characteristic odor. The eggs are pale yellow, grayish, or brownish, smooth, elongate, cylindrical or nearly spherical, with the two micropylar organs very much reduced in size. They are deposited in single or double rows on the stems of grasses and other plants.

The larvæ differ from their close relatives, the ant lions, in having the head deeply invaginated behind to receive the neck, in rows of conspicuous tubercles along the back and sides, and in the presence of trumpet-shaped dolichasters and complex scales. The mandibles are toothed, strongly curved, and very sharp; the tibiae and tarsi are partially or wholly united. They live on plants, under stones or debris on the ground, and ambuscade their prey. Pupation occurs in a silken cocoon in the habitat of the larva.

This large cosmopolitan family of approximately 50 genera and 210 species is distributed throughout all of the continental land masses. In Europe it is represented by at least three species of *Ascalaphus* Fab. and by *Puer maculata* Olivier; in North America by *Neuroptynx* McClendon, *Uhlodes* Currie, and *Colobopter* Rambur; in Australia by *Acomonotus* McL. and *Suhpalacsa*¹ Lefebure and 12 species; in Africa by *Suhpalacsa*, *Nephoneura*, *Ulula* Rambur, and *Pseudoptynx* Weele; in India by *Hybris* Lef. and *Suhpalacsa*; in Japan by *Ascalaphus*, *Protidricerus*, *Hybris*, and *Acheron*.

The average wing spread is from 40–50 mm. *Ascalaphus ictericus* Charp. var. *siculus* Rambur of Europe has an expanse of 33 mm. and *Haploglenius luteus* Walker of South America 107 mm.

Family MANTISPIDÆ Westwood 1840 (Man-tis'pi-dæ, from the Greek *μάντις*, a prophet; because of their resemblance to the mantis). German, Fanghaften. French, Mantispides. False Mantids, Mantispids.

The adults are medium-sized insects which so greatly resemble the mantids that they are commonly mistaken for those peculiar predators. Their raptorial type and use of the front legs and the general habits of the adults are strikingly parallel. The head is wider than long, with large hemispherical eyes, without ocelli, and with short setiform antennæ. The prothorax is greatly elongated and the forelegs inserted at the front. The two pairs of wings are similar and rather narrow, and the venation resembles somewhat that of the CHRYSOPIDÆ. The adults are very rare insects and have never been taken in great numbers. They occur on various types of vegetation, where they await the arrival of insect prey. Specimens are usually captured by beating or sweeping.

The eggs are white or reddish, smooth, oval, with a flat micropylar knob, and are supported on short stalks about twice the length of the egg. They are laid in clusters and somewhat resemble the fruiting bodies of certain mosses except in color.

The larvæ are of two forms; the first instar is thysanuriform with squarish

¹ Anagram of *Ascalaphus*.

head, three- to five-segmented antennæ, short straight mandibles and maxillæ, and three- or seven-segmented labial palpi. The legs have two claws and an empodium. These young larvæ are active hunters but when they have found suitable food reserves in the form of egg sacs of the *Lycosa* spiders or nests of *Polybia* wasps they enter upon a parasitic existence during the second and later instars and become robust and eruciform, resembling white grubs but with small

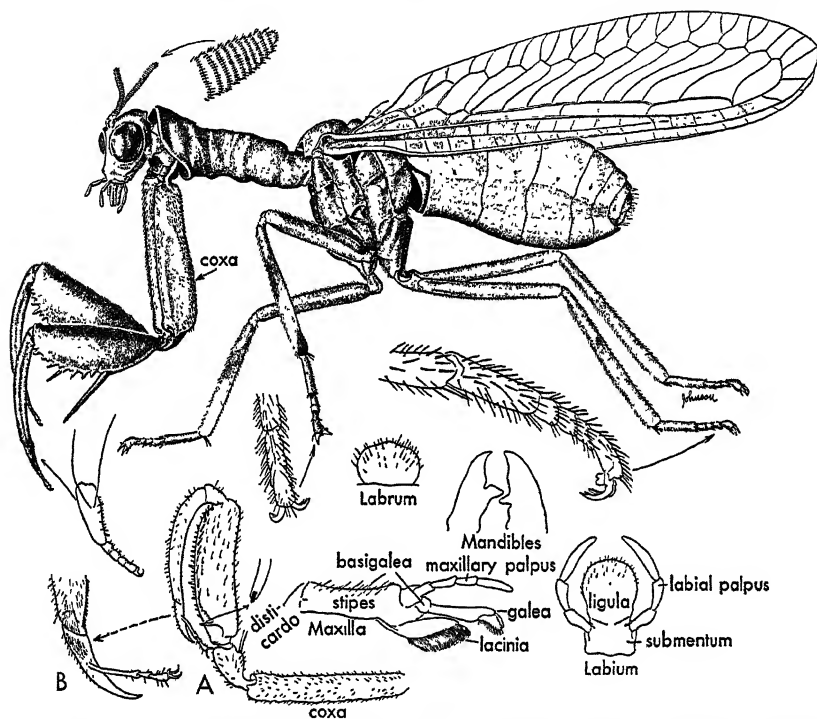


FIG. 138. One of the commonest North American mantispids, *Mantispa brunnea occidentis* Banks. A, leg and B, tarsus of an undetermined Arizona species.

heads and atrophied legs. When mature, they spin cocoons and pupate within the last larval skin.

The family, not a large one, contains about 15 genera and 170 species scattered throughout the world. *Mantispa pagana* Fab. (*M. styriaca* Poda) is the only common European species. It is yellowish-brown, from 15–20 mm. long, and has a wing expanse of 34 mm. In North America there are no less than six species of which *M. brunnea* Say, 22 mm. long, is the commonest. In Australia there are three common species, the largest being *M. australasica* Westwood with a wing expanse of 50 mm. One of the smallest species, *Mantisphilla pygmaea* Stitz of Africa, has a wing expanse of only 10 mm. whereas *Euclimacia flavicincta* Stitz of the Solomon Islands has an expanse of 55 mm.

Symphrasis Hagen is the only other North American genus, which, with *Mantispa* Illiger and *Drepanicus* Blanchard, also inhabits South America. *Symphrasis varia* (Walker) lives in the nests of wasps, *Polybia* spp., in Brazil.

The genus *Euclymacia* contains slender-waisted, wasp-like species in Africa and Australia.

In Japan there are at least four genera and six species.

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CHAPTER XXVIII

25. Order RAPHIIDIDEA ¹ Burmeister 1835

(Ra-phid'i-o'de-a, from the Greek *ῥαφίς*, a needle; referring to the ovipositor of the female.) German, Kamelhalsfliegen.

French, Raphidides.

Raphidians, Snakeflies, Serpentflies.

Adults terrestrial, small to medium-sized; elongate; fragile insects; with complex metamorphosis; biting mouth parts; setiform, many-segmented antennæ; slender neck-like prothorax much longer or shorter than the head; prominent compound eyes; three ocelli present or absent; short legs; two pairs of similar, many-veined wings; female with long slender ovipositor.

Larvæ largely arboreal; thysanuriform; with few long body hairs; large polished head and prothorax; short antennæ; without cerci.

SUMMARY OF ANATOMICAL CHARACTERS

<i>External — Adults</i>	<i>External — Larvæ</i>
Size — small to medium.	Size — medium, 20-30 mm. long.
Shape — elongated, somewhat cylindrical.	Shape — thysanuriform, elongated.
Exoskeleton — thin, elastic, soft or partly hardened.	Exoskeleton — thin and elastic.
Vestiture — a few long hairs.	Color — dark gray, brown, blackish with paler bands.
Color — mostly brown, reddish, and black, often with brighter lines and bands.	Head — large, prognathous, polished.
Head — elongated, usually much longer than wide, and usually constricted into a neck; hypognathous.	Eyes — in two groups of four to seven each.
Antennæ — filiform, 35-70 segmented, remotely inserted.	Antennæ — setiform, three- or four-segmented.
Eyes — compound — prominent, widely separated.	Mouth parts — similar to those of adults.
Ocelli — three or absent.	Thorax — prothorax large, elongated, and polished.
Mouth parts — biting.	Legs — short.
Clypeus — large, wide.	Spiracles — large pair on prothorax.
Labrum — wide, emarginated.	Abdomen — 10-segmented.
Maxillary palpi — four-segmented.	Spiracles — seven visible pairs.
	Cerci — absent.

¹ The lack of uniformity in the constitution and spelling of this order has led to considerable confusion in entomological literature. The following names and many others have been used for these insects by different workers: RAPHIDIDES Leach 1815; RAPHIDIINA Newman 1834; RHAPHIDIODEA Burmeister 1835; LEPTOPHYA Brauer 1885; RAPHIIDIDEA Handlirsch 1903, 1906; EMMENOGNATHA Börner 1904. Handlirsch 1925 and Weber 1933 have accepted the priority of Leach; Stitz 1928 has used RAPHIDIINA of Newman, and Carpenter 1936 has employed the term RAPHIIDIDEA erected by Burmeister as modified in spelling by Brues and Melander 1910. *Rhaphidia* was the pre-Linnæan spelling of the original genus.

SUMMARY OF ANATOMICAL CHARACTERS—*Continued*

External — Adults	Internal — Adults
<p><i>Labial palpi</i> — three-segmented.</p> <p><i>Mandibles</i> — small, with three or four teeth.</p> <p>Thorax — <i>Prothorax</i> — longer or shorter than head, slender and neck-like.</p> <p><i>Meso- and metathorax</i> — both shorter than wide.</p> <p><i>Legs</i> — slender, first pair attached at base of prothorax. <i>Tarsi</i> five-segmented, third segment enlarged and flattened, fourth very small.</p> <p><i>Wings</i> — two pairs; similar in shape and venation; hind pair somewhat smaller; pterostigma large.</p> <p><i>Spiracles</i> — two pairs.</p> <p>Abdomen — ten-segmented.</p> <p><i>Genitalia</i> — male abdomen terminating in a hood-shaped epiproct and a pair of harpagones. Female with long slender ovipositor.</p> <p><i>Spiracles</i> — eight pairs.</p>	<p>Very little known</p> <p>Alimentary System. Long food sac at posterior end of crop.</p> <p><i>Salivary glands</i> — a pair of tubes extending half the length of the body.</p> <p><i>Mid-intestine</i> — large.</p> <p><i>Malpighian tubes</i> — well developed; six in number, four attached at their tips to colon.</p>

This remarkable group of insects has long been placed in the order NEUROPTERA, largely because of the general type of wing venation, and has only

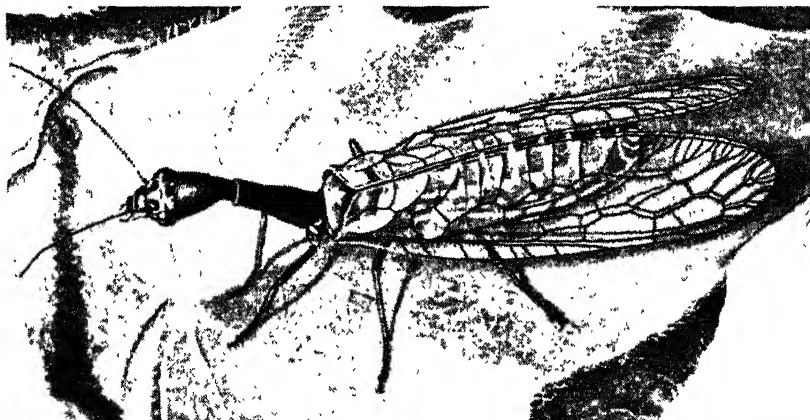


FIG. 139. The European raphidian, *Raphidia ratzeburgi* Brauer. (Photographed from Robert, 1936.)

within recent years been given order rank. It constitutes a relatively small group comprising five genera and approximately 60 species. Concerning the distribution Carpenter (1936) states:

"The geographical distribution of the snake-flies is particularly interesting since it conforms to that frequently found in groups of animals and plants which are geologically old. Only two of the above genera, *Agulla* and *Inocellia*, are represented in the existing North American fauna, however. *Raphidia*, as characterized above, occurs in Europe and Asia; *Erma* only in Northeastern Spain; and *Fibla* in southern Europe. *Agulla*, the most widely distributed genus, inhabits not only part of North America, but also Chile, Central America, and part of Asia; and *Inocellia* occurs in Central Europe, Asia, and northern Africa, as well as part of North America. It is apparent, then, that with the exception of the single Chilean species, *Agulla herbsti* (Peters.), the Raphidiodea are confined to the Northern Hemisphere, and that fully ninety-five per cent of the species inhabit only the Holarctic regions. No snake-flies have yet been found in the Australian or Ethiopian regions, and it is extremely doubtful that any native species will ever be secured there. In the Nearctic region the insects are confined to the area west of the eastern slopes of the Rocky Mts., extending northward into the southern part of British Columbia, as far as latitude 52°. In view of the wide distribution of the snake-flies in Europe, their absence from the eastern half of North America is particularly striking and has some bearing on the question of the origin of the Nearctic species, as I shall show later. In all



FIG. 140. Larva of *Raphidia oblita* Hagen.

probability the eastward migration of these insects has been prevented by the extensive arid areas just east of the Rocky Mountains. Since the snake-flies pass through their immature stages under the bark of pine, fir, eucalyptus, and related trees, they are always absent from regions which are too arid for these trees. In view of the poor flying capacity of these insects, their occurrence in pine forests on the peaks of the 'island' mountain ranges of the desert of Arizona is therefore more than a little remarkable.

"The two families of Raphidiodea which occur in the Nearctic region are not equally distributed in that area. The Raphidiidae have the greater range, including the entire Californian and most of the Rocky Mountain regions, as defined by Wallace; the Inocelliidae, on the other hand, have only been found (so far as I am aware) in the Californian region."

As has already been intimated, snakeflies are an ancient group of insects. The oldest known specimens are from the Jurassic of Turkestan. They have also been taken in Oligocene Baltic amber and these, according to Carpenter (1936), reveal "that by the time of the Oligocene, at least, the snake-flies already included the two types which are now regarded as families. . . . In the case of the Raphidiodea, it seems evident that while new genera have been evolved since the Miocene, at least two of the Tertiary genera (*Raphidia* and *Fibla*) have persisted until the present time. . . .

"In view of these geological data, the composition and distribution of the snake-fly fauna in North America is particularly interesting. The two genera

which occur in the Miocene of Colorado no longer exist in the New World, but are confined to the Palearctic region, one (*Fibla*) being restricted to the southern part of Europe. This is strong evidence that the present snake-fly fauna of North America has been newly formed since the Miocene, the Mid-Tertiary fauna having been exterminated. The restriction of the recent genera in North America to the Rocky Mountain and Californian regions points to the conclusion that the present snake-fly fauna of North America has been derived from eastern Asia through Alaska. This migration could easily have extended southward along the Pacific coast into South America, giving rise to the two isolated species of *Agulla* which occur in Central America and Chile."

KEY TO FAMILIES

(After Carpenter 1936)

1. Ocelli present; pterostigma bisected by a veinlet; antennal segments smaller at bases **RAPHIDIIDÆ**
2. Ocelli absent; pterostigma not bisected by a veinlet, antennal segments cylindrical **INOCELLIIDÆ**

Family RAPHIDIIDÆ Stephens 1836 (Raph'i-di'i-dæ: see meaning under order name). Long-necked snakeflies.

This, the dominant family, includes the genera *Raphidia* Linnæus 1758, the first to be described and for many years the only genus and "catch-all" for all the various species described: *Erma*¹ Navás 1918; and *Agulla* Navás 1914, the most widely distributed genus, which now includes nearly all species that were placed in *Raphidia*.

The common raphidian, *Agulla adnixa* (Hagen) (*Raphidia*), is the commonest and one of the most widely distributed species in North America, and yet very little is known as to its biology. It ranges from the Pacific seashore to the crests of the Sierra Nevada and of the Rocky Mountains to an elevation of at least 9,000 ft.

Agulla arizonica (Banks) and *A. unicolor* Carpenter also have a similarly wide distribution in western North America.

There are at least 12 species of *Raphidia* in Europe.

Raphidia hermandi Navás occurs in Japan.

Family INOCELLIIDÆ Navás 1916 (In'o-cell-i'i-dæ, from the Latin; meaning without ocelli). Inocellids.

This family embraces but two genera, *Inocellia* Schneider 1843, which is Ne-arctic and Palæarctic, and *Fibla* Navás, which is European.

The American species, *Inocellia inflata* (Hagen) (*Raphidia*) and *I. longicornis* Albarda, have been collected only along the Pacific coast from southern British Columbia to southern California and to western Nevada.

Inocellia crassicornis Schummel is a Japanese species.

¹ The genus *Erma* was placed in a separate family, *ERMIDÆ*, by Lestage 1928.

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CHAPTER XXIX

26. Order MECOPTERA¹ (Packard 1886) Comstock 1895

(Me-cop'ter-a, from the Greek *μῆκος*, magnitude, length, + *πτερά*, wings; referring to the long wings.) German, Schnabelfliegen. French, Mouches-scorpions.

Scorpionflies.

Small to medium-sized; slender; predacious insects with biting mouth parts; complex metamorphosis; head usually greatly elongated and vertical; antennæ long, filiform, many-segmented; compound eyes large, widely separated; ocelli three or none; legs long, slender, strong; wings four, similar in shape, size, and venation, held flat or roof-like, or rudimentary or absent; male genitalia bulbous or inconspicuous; cerci short, simple or two-segmented.

Larvæ eruciform, caterpillar-like, with three pairs of legs and from none to four-nine pairs of prolegs.

SUMMARY OF ANATOMICAL CHARACTERS

<i>External — Adults and Larvæ</i>	<i>Internal — Adults</i>
Size — medium to large.	Digestive System. Comparatively simple.
Shape — long and slender, cylindrical or slightly compressed laterally.	<i>Alimentary canal</i> — nearly a straight tube with convolution in the hind intestine.
<i>Larvæ</i> — eruciform, caterpillar-like, often C-shaped.	<i>Œsophagus</i> — short, slender, enlarged in two places.
Exoskeleton — fragile or leathery and tough, usually smooth and devoid of hairs.	<i>Proventriculus-like</i> organ provided with a lining of setæ.
<i>Larvæ</i> — thin and delicate.	<i>Salivary glands</i> — a pair of tubes.
Color — cryptic or bright, wings often spotted.	<i>Malpighian tubes</i> — six.
<i>Larvæ</i> — white or pale.	Circulatory System. Normal.
Head — hypognathous, normal, or greatly prolonged and beak-like.	Respiratory System. Two pairs thoracic and eight pairs of abdominal spiracles.
<i>Eyes</i> — compound — large and widely separated.	Well-developed tracheal system.
<i>Ocelli</i> — usually three in triangle or absent.	Nervous System. With normal cephalic regions; three thoracic and six abdominal ganglia.
<i>Larvæ</i> of <i>Panorpa</i> with 20–28 simple eyes on either side.	Reproductive System.
<i>Antennæ</i> — filiform, long, many-seg-	<i>Male</i> — a pair of testes of three follicles, each vas deferens much convoluted. Two vasa deferentia open

¹ This name is a modified form of MECAPTERA erected by Packard in 1886. Many other names have been suggested for these insects, such as PANORPATÆ Latreille 1802; PANORPIDA Leach 1815; PANORPACEA Burmeister 1829; PANORPINA Stephens 1829. Modern workers who have adopted Comstock's designation are: Tillyard 1926, Metcalf and Flint 1928, Crampton 1931, Carpenter 1931, Brues and Melander 1932, Weber 1933, Imms 1936.

SUMMARY OF ANATOMICAL CHARACTERS — *Continued*

<i>External — Adults and Larvæ</i>	<i>Internal — Adults</i>
<p>mented (16-20 or 40-50). <i>Larvæ</i> of <i>Panorpa</i> — four-segmented.</p> <p>Mouth parts — biting, rather small, but strong.</p> <p>Mandibles — long, slender, with one to three apical teeth.</p> <p>Maxillæ — normal, with five-segmented palpi, galea and lacinia hairy. <i>Larvæ</i> with four-segmented palpi (<i>Panorpa</i>).</p> <p>Labium — submentum greatly elongate; mentum short; ligula absent; palpi one- to three-segmented or merely lobes. <i>Larvæ</i> with three-segmented palpi.</p> <p>Thorax — free; prothorax very small; meso- and metathorax subequal.</p> <p>Legs — normal to very long and slender; coxæ long; tibiae with apical spurs; tarsi five-segmented, terminating in a pair of claws or in a single claw, toothed or pectinate or simple.</p> <p>Wings — absent, vestigial, or two pairs; held roof-like or flat; similar in size, shape, and venation; slender; pterostigma usually present and with cross veins. Macrotrichia usually present on longitudinal veins; microtrichia on wing membrane.</p> <p>Spiracles — two pairs. <i>Larvæ</i> with one.</p> <p>Abdomen — nearly cylindrical; 10-segmented in adults and larvæ.</p> <p>Genitalia — Male — ninth segment with specialized organs forming noticeable enlarged gonocoxites, resembling sting of scorpion, present in some forms. Female with ovipositor.</p> <p>Cerci — simple in male; two-segmented in female.</p> <p>Spiracles — six, seven, or eight pairs. <i>Larvæ</i> with eight pairs.</p>	<p>separately, and a pair of accessory glands also open into the median vesicula seminalis.</p> <p>Female — each ovary composed of 10-25 polytrophic ovarioles. Two oviducts unite to form common canal opening into genital pouch which also receives duct from the spermatheca and opens on the ninth sternite.</p>

The members of this order are among the most peculiar and perhaps the most homogenous of the many groups of insects. With the exception of the two primitive Australian families, CHORISTIDÆ and NANNOCHORISTIDÆ, which have nearly the normal type of head, the mecopterans have a peculiar elongation of the head which at once sets them apart from all the closely related neuropteroid forms. The wings are frequently spotted or clouded, and the unusual enlargement of the apical abdominal segments of the males are also aids in recognizing them. All of the known forms are terrestrial,

but it is thought that the immature stages of the NANNOCHORISTIDÆ are aquatic. The biology and ecology of the order have been studied very little, and the immature forms of only half a dozen species have been carefully observed and described. Therefore, this order offers unusual opportunities for original inquiries.

In general it is said that the adults and larvæ are carnivorous and saprophagous, but it is also recorded that some adults feed on the nectar and petals of

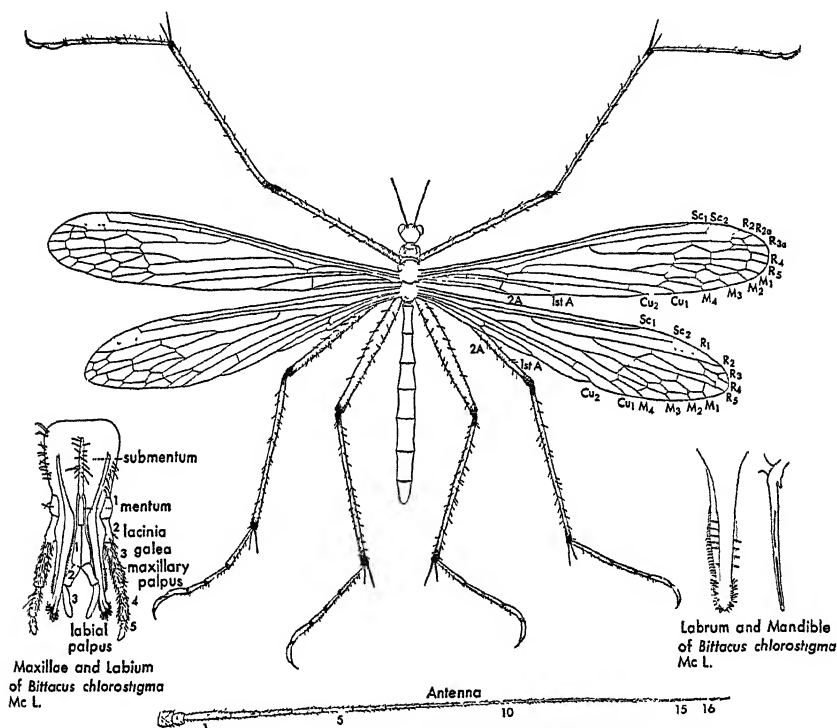


FIG. 141. The scorpionfly, *Bittacus chlorostigma* McLachlan, and antenna and mouth parts.

flowers, and on fruits and mosses. Adults and larvæ of *Boreus* feed upon mosses and the larvæ also upon vegetable matter in the soil. The few observed eggs are spherical, elongate, or of a cubical pattern and are laid in masses in the soil. The larvæ are eruciform and caterpillar-like with from four to eight pairs of abdominal prolegs in *Panorpa* and *Apterobittacus* or C-shaped and without prolegs in *Boreus*. Pupation takes place in a cell in the soil, rotten logs, vegetable debris, or other habitat, and always in damp situations. The adults have been found abundant only rarely in certain few places although they are quite common in many parts of the world. The males of some species secrete a luring fluid from the mouth which attracts the females for mating.

This small order represents about 20 genera and some 310 species, of which three fourths occur in the subtropical and temperate regions and the remainder in the tropics. The species are roughly distributed as follows: Eastern Asia 65, Africa 19, Australia and New Zealand 13, Europe 30, India and Malaysia 20, Central America 10, North America 30, and South America 15.

The fossil record of this order is an ancient one. According to Tillyard (1926) there are in the Lower Permian of Kansas small undescribed species allied to the Australian family CHORISTIDÆ which are the oldest recognizable insects with complex metamorphosis. Forms common to Australia designated as the order PARAMECOPTERA¹ Tillyard, which also bears relationships to the LEPIDOPTERA and the TRICHOPTERA, have been found in the Upper Permian of Belmont, New South Wales, and in the Upper Trias of Ipswich, Queensland. Specimens of *Bittacus* and *Panorpa* occur in the European Tertiary Amber, in Colorado Florissant, and in English Lias.

KEY TO FAMILIES

- | | | |
|---|------------------------|--------|
| 1. Without ocelli | MEROPIDÆ | p. 405 |
| With ocelli | 2 | |
| 2. Apterous or with vestigial wings | BOREIDÆ | p. 403 |
| Wings well developed | 3 | |
| 3. Head globular (Australia) | NANNOCHORISTIDÆ | p. 404 |
| Head prolonged | 4 | |
| 4. Wings with very many small irregular cells and with small distinct anal area (Chile) | NOTIOTHAUMIDÆ | p. 405 |
| Wings with mostly linear cells and without distinct anal area. | 5 | |
| 5. Head only slightly prolonged; male palpi greatly enlarged (Australia) | CHORISTIDÆ | p. 405 |
| Head greatly prolonged, male palpi not swollen | 6 | |
| 6. Tarsi with two claws | PANORPIDÆ | p. 404 |
| Tarsi with one claw | BITTACIDÆ | |

Family BITTACIDÆ Enderlein 1910 (BITTACUSIDÆ Handlirsch 1906)
(Bit-tac'i-dæ, from the Greek *βιττακος*, a parrot).

Rather long, slender alate species with elongated head; slender antennæ less than half as long as the fore wings; long and slender labium and mandibles; the fourth and fifth segments of the tarsi with fine teeth on the inner margins and the fifth closing over the fourth like a pocket knife blade, and with single claws; apterous or with narrow, somewhat petiolate wings; long slender abdomen; and the males without bulbous genitalia.

The adults frequent grasses and bear a striking resemblance to crane flies which are often associated with them. A number of the species cling by the forelegs and capture and hold living prey with the hind legs. The food consists chiefly of small insects which may be overcome by these greedy predators.

¹ This order also contains the Upper Triassic family ARCHIPANORPIDÆ and the modern family MEROPIDÆ according to Tillyard.

Bittacus Latr., the dominant genus, has a cosmopolitan distribution, there being at least nine North American species. *Harpobittacus* Gerstaecker has two species in Australia. Concerning them Tillyard, 1926, states "The life history of these insects is unknown except that they lay peculiar, hard, cubical eggs with concave faces, which they appear to drop freely on the ground."

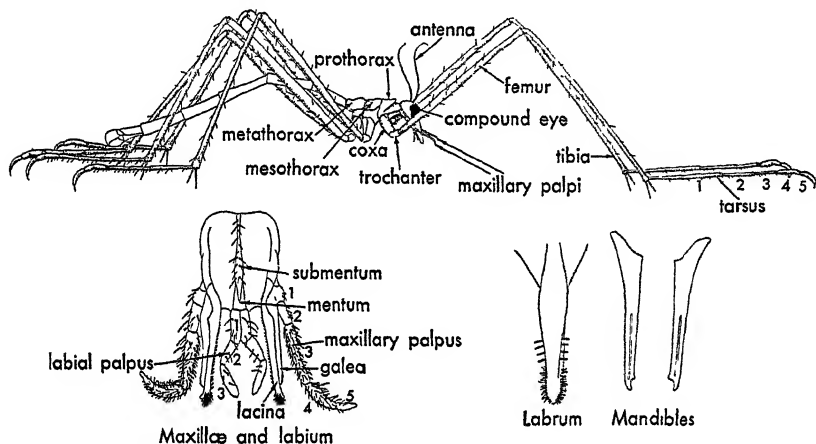


FIG. 142. A wingless scorpionfly, *Apterobittacus apterus* (McLachlan), and mouth parts.

The California *Apterobittacus apterus* McLachlan is a most peculiar species the larvæ of which have recently been studied by Applegarth (1939).

Family BOREIDÆ Stephens 1829 (Bo-re'i-dæ, from the Greek βορέας, the north wind, the north). Snow Scorpionflies.

Members of this family are very small, peculiar, black species from 2.5–3 mm. long which are wholly apterous or have only vestigial bristle-like wings in the male and scale-like lobes in the female. They have no ocelli, the legs are long and slender, and the female has a long ovipositor that may be nearly as long as the body.

The larvæ are small, almost hairless, C-shaped, white or yellowish, and grub-like, with three pairs of thoracic legs and with yellowish-brown head. They live in moss, vegetable debris, rotten wood, or under stones, where pupation also occurs in a cell. The food of the larvæ is thought to be wholly vegetable while the adults are probably predacious and saprophagous. The adults hop and look like minute grasshoppers. At times they appear in great numbers on the surface of the snow in winter but are most often collected under stones, logs, and vegetable litter. This small family consists only of about 15 species occurring in the Holarctic regions.

The commonest European species is *Boreus hyemalis* (Linn.), which has been studied by a number of observers. The larvæ are frequently taken at the roots of the mosses growing on the floor of the forests during the winter months,

and adults may also appear during this season. *B. westwoodi* Hagen is also European.

In the United States there are 10 or more species. The two best known eastern species are *Boreus brumalis* Fitch and *B. nivoriundus* Fitch, and two common western species are *B. unicolor* Hine and *B. californicus* Packard.

Family PANORPIDÆ Samouelle 1819 (Pa-nor'pi-dæ, from the Greek *πᾶν*, all, + *ἀροη*, sickle, goad; owing perhaps to the peculiar genitalia of certain of the males and females). True Scorpionflies.

The members of this family have long and narrow wings which are often conspicuously spotted. The males usually have the bulbous genitalia; three ocelli are present; and the pair of claws is simple or pectinate.

The family is fairly large, consisting of approximately five genera and 140 species distributed throughout the Northern Hemisphere and also in Indo-Malaysia.

The adults have variable feeding habits and their food consists of living insects, mites, and other small animal life as well as fruits, flowers, and other vegetable matter. The ovoid eggs of known species are laid in batches of 100 or more in the soil. The larvæ are caterpillar-like, having well-developed head, thoracic legs, and a variable number of prolegs, usually eight pairs. The body may also support segmented, spine-like processes on the dorsum of the 10 abdominal segments, which increase in length posteriorly. The eyes are arranged in groups of 20 to 28 on each side of the head, the antennæ are

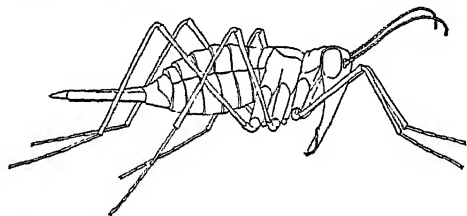


FIG. 143. The minute apterous snow scorpionfly, *Boreus californicus* Packard.

four-segmented, the mandibles toothed, the maxillary palpi four-segmented, and the labial palpi three-segmented. The nine pairs of spiracles are distributed one pair on the prothorax and one pair on each of the first eight abdominal segments.

These data are given for the Asiatic species *Panorpa klugi*

McLachlan by Miyake (1912) who has made a study of the life history of the species. *Panorpa communis* Linn. is fairly abundant throughout many parts of Europe. Of the more than 40 North American species, the commonest ones are *P. nebulosus* Westwood and *P. rufescens* Rambur. In the western states *Brachypanorpa oregonensis* (McLachlan) (*Panorpodes*) is the only representative of the family.

Family NANNOCHORISTIDÆ Tillyard 1918 (Nan'no-cho-ris'ti-dæ, from the Greek *νᾶνος*, dwarf; referring specifically to small CHORISTIDÆ).

A very small family of active dwarf species with a wing expanse of only 15 mm. The adults have a globular head with short rostrum and antennæ about half as long as the fore wings; and mouth parts simulating somewhat the

suctorial type of certain primitive DIPTERA. The immature forms are unknown. The genus *Nannochorista* Tillyard with four species occurs in Australia and two species in South America. *Choristella* Tillyard with one species is found in New Zealand.

Family CHORISTIDÆ Tillyard 1926 (Cho-ris'ti-dæ, from the Greek χωριστός, separated; referring to the marked difference between these species and those previously known).

A small family consisting of but two genera, each with two species, confined to Australia. The head and rostrum are short, the antennæ as long as or longer than the fore wings, labrum broad, mandibles pointed and simple, and the males with bulbous genitalia.

Chorista australis Klug occurs in damp places where also abound the semi-transparent pinkish larvæ which inhabit small tunnels in the bare soil and under vegetable debris. The food consists of fungi, lichens, mosses, and vegetable debris. The spiracles are remarkable in being disk-like with a circular row of 27 openings around a central aperture.

Tæniochorista pallida E. Petersen is remarkable for the enlarged palpi of the male which exude an attractive fluid that is a mating lure for the females.

Family NOTIOTHAUMIDÆ Brues and Melander 1932 (No'ti-o-thau'mi-dæ, from Greek νότος, the south wind, the south, + θαύμα, a wonder, a marvel; referring to this unusual South American species).

This family is restricted to one genus and a single species, *Notiothauma reedi* McLachlan, which occurs in Chile. Crampton (1931) has characterized it as "the living fossil — the last remnant of a primitive relict fauna, representing as clearly as any living form the type ancestral to the rest of the Mecoptera."

Family MEROPIDÆ Handlirsch 1906 (Me-rop'i-dæ, from the Greek μέροψ, a bird, bee eater; application uncertain).

In this family the wings are quite wide with many cross veins in the subcostal area, the venation open and regular, and an anal area evident. There are no ocelli, and the genitalia of the males include a pair of long, stout, pincer-like claspers.

The family comprises only one genus and a single species, *Merope tuber* Newman, which is a very rare insect occurring in the eastern United States.

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CHAPTER XXX

27. Order TRICHOPTERA ¹ Kirby 1813

(Tri-chop'ter-a, from the Greek *θρίξ, τριφός*, hair, + *πτερά*, wings; referring to the hairy wings.) German, Frühlingsfliegen, Köcherfliegen. French, Frigane.

Caddisflies, Cadises, Caddiceflies, Caseflies, Water Moths.

Small to medium-sized, diurnal and nocturnal insects with complex or holometabolic metamorphosis and feeble biting mouth parts. Long, filiform, many-segmented antennæ; well-developed compound eyes; three or no ocelli; two pairs of wings clothed with hairs and scales with many longitudinal and few cross veins, hind pair widest and with anal fold, both pairs usually folded roof-like over body in repose; well-formed legs for walking and running, tibiae with spurs, five-segmented tarsi; nine- or 10-segmented abdomen; one- or two-segmented cerci. Larvæ aquatic; campodeiform or eruciform with chitinated and pigmented anterior region and soft abdomen terminated by a pair of prolegs or caudal hooks. Usually living in cases in which pupation also occurs.

Caddisflies according to Needham and Lloyd (1930) constitute the largest single group of predominantly aquatic insects. They are peculiar hairy insects which frequent fresh and rarely salt water and although they are not all strong fliers, many species may often be seen engaged in a very lively dance over and near the surface of the water, especially on still, warm spring and summer evenings. Certain few species are diurnal, but the great majority rest during the day, and take wing at or just following sunset for their nocturnal mating frolic. Then they may often be attracted to lights in great numbers. A few diurnal forms are said to visit flowers. They are quick on foot, run upon alighting, and take off with a jump. Their flight, while usually uncertain and erratic, may assume brisk circular movements. Although they somewhat superficially resemble small moths because of their vestiture, their movements and general anatomical features readily relegate them to a separate and distinct group of insects. They are perhaps called caddisflies, or their larvæ caddisworms, because of the ability of the latter to construct and line with silk the cases in which they live. The adults are usually cryptically colored in shades of brown, tan, gray, or smoky black although certain species are much more brightly colored.

¹ The members of this group were classed with the NEUROPTERA by Linnæus 1758 and with the SYNISTATA by Fabricius 1775. Other important names among the many assigned to them are: PHRYGANIDES Latreille 1805, AGNATHES Cuvier 1805, PHRYGANITES Latreille 1810, PLACIPENNES Latreille 1825, PHRYGANINA Newman 1834, PHRYGANIDÆ Kirby 1837, PHRYGANEOIDEA Burmeister 1839, PHRYGANARIA Hæckel 1896, TRICHOPTEROS Navás 1903, PHRYGANOIDEA Handlirsch 1903.

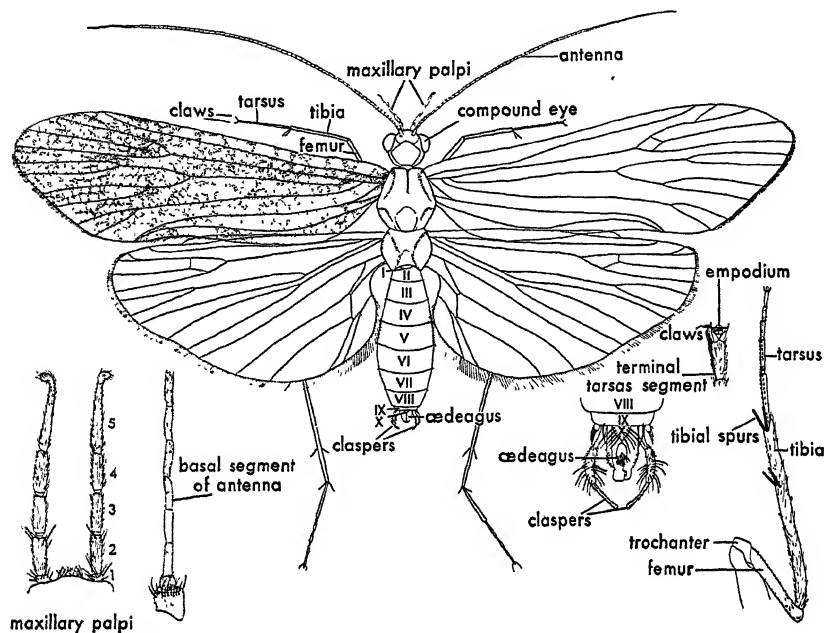


FIG. 144. A caddisfly and certain anatomical features.

EXTERNAL ANATOMY

Larvæ	Adults
Campodeiform or eruciform. Head-thorax region pigmented and armored.	Fragile, moth-like, hairy.
Head rather small, chitinated, pigmented, straight or bent downwards.	Head small and free.
Compound eyes absent.	Compound eyes large, wide apart.
Ocelli six, grouped closely together in a single compact cluster resembling a small compound eye.	Ocelli three, often obscured by hairs or totally absent.
Antennæ very small, setiform, four- or five-segmented, with or without a distal bristle and two large sensoria.	Antennæ long, filiform, multi-segmented. Basal segments may be much enlarged.
Mouth parts much stronger than in the adult. Labrum a small chitinated plate, usually wider than long, with five or six bristles.	Mouth parts poorly developed. Labrum short and stout or rarely greatly elongated. Pilifers or lateral processes sometimes present.

EXTERNAL ANATOMY—*Continued*

<i>Larvæ</i>	<i>Adults</i>
<p>Mandibles strong and with one or two cutting ridges and more or less dentate. Maxillary palpi are four- to five-segmented. Labial palpi rudimentary, two-segmented.</p>	<p>Mandibles well formed or rudimentary, or almost absent. Maxillary palpi four- or five-segmented. Galea small or wanting. Lacinia absent. Hypopharynx well developed. Labial palpi three-segmented.</p>
	<p>Wings—two pairs normally present. Females of some species almost apterous. Hind wings aborted in both sexes of some species. Fore pair usually narrow. Venation primitive—many longitudinal and few cross veins. Macrotrichia or hairs abundant on membrane and veins of most species, almost absent on others.</p>
<p>Prosternal horn present in certain families of eruciform larvæ only.</p>	<p>Scales may also be present, coupled by jugal lobe, anal fold, or hooks.</p>
<p>Legs short and stout for clinging, crawling, and swimming; and armed with hairs and spines. Coxæ large and strong. Tarsi one-segmented. Claws single, long, stout, simple or with a tooth or basal spines.</p>	<p>Legs long and slender for running. Coxæ much elongated. Tibix with median and apical movable spurs. Tarsi five-segmented. Claws—one pair with empodium or a pair of pulvilli.</p>
<p>Abdomen naked or slightly hairy, with soft integument and often with chitinized dorsal plates. Mid-dorsal and lateral processes may be present on the first segment. A pair of caudal hooks or prolegs on the last segment serve to anchor the larva in its case or to a support.</p>	<p>Abdomen 10-segmented. Fifth segment may be specialized to form lateral pockets or into a slender process. Eighth segment of ♀ may carry a subgenital plate. Ninth segment of ♂ with one- or two-segmented cerci or claspers and a pair of lateral processes. 10th segment greatly reduced and may have a dorsal process and a pair of preanal appendages.</p>
<p>Gills absent in first-hatched larvæ and throughout life in certain species. Filamentous tracheal gills, variously arranged, are present in most cases; anal blood gills present in some.</p>	<p>Spiracles—two thoracic and eight abdominal.</p>

INTERNAL ANATOMY

<i>Larva</i>	<i>Adult</i>
Internal anatomy quite thoroughly studied.	Internal anatomy of adult not extensively known.
Alimentary canal distinctly divided into fore intestine, mid-intestine, and hind intestine. Surface of mid-intestine with transverse folds.	Alimentary canal somewhat shortened.
Two pairs of salivary glands.	Stomach small. Intestine partly coiled.
Six Malpighian tubes	Six Malpighian tubes
Silk glands very large, occupying much of the anterior portion of the body. Spinneret situated on the middle of the front margin of the labium.	Silk glands—modified during pupation into salivary glands in the imago.
Accessory excretory organs, known as Gilson's glands, occur in many species.	
Cephalic, three thoracic, and six to eight abdominal ganglia.	Cephalic, three thoracic, and seven abdominal ganglia.
Respiration through the integument or by means of gills.	Spiracular and tracheal respiration.

The eggs are loosely deposited in transparent gelatinous masses or strings in the debris at the bottom of water courses or attached to rocks, roots, logs, and aquatic plants. Upon hatching, most of the eruciform larvæ begin to construct characteristic cases which are enlarged as needed. Some species make very simple cases on stones, others spin elaborate ones from many kinds of materials, but usually each species adheres to a more or less definite pattern; a few burrow holes in bits of wood in which they are concealed and still others live in loose bag-like or funnel-shaped webs which are attached at the anterior end and suspended loosely in the current. Those building the movable cases attach themselves to the posterior end of their abodes by means of the caudal prolegs. They allow only the armored head, thorax, and legs to protrude when swimming, feeding, or dragging their cases about, and withdraw entirely into the same at will. Thus it is that one often sees small bits of sticks, leaves, and peculiar forms of pebbles, sand, and other shapeless objects moving on the bottoms in a slow jerky fashion. Species living in swift waters often construct loosely woven bags or funnel-shaped abodes, attached only at the anterior end and kept inflated and in constant motion by the current. The campodeiform larvæ either live unprotected in the debris or build more stationary abodes, supplemented by catching nets which screen out food for the occupant. Often the stationary cases are constructed in a series close together, but not usually

actually contacting each other. Some species, however, literally pile up in masses.

Altogether they form one of the most interesting and remarkable groups of aquatic animals. Their food habits are varied. Probably the greater number of species are herbivorous, feeding upon diatoms, algæ, and higher forms of aquatic plant life. A large number of species are mostly carnivorous, devouring small crustaceans, the larvæ of chironomids, simuliids, and other small



FIG. 145. Gelatinous egg masses of a caddisfly occurring in shallow pools of water in the Sierra Nevada Mountains of California.

aquatic animals, while still others have been found to be herbivorous during the fall and carnivorous in spring and summer.

To the country lad, the caddisworms are a source of fish bait always available in a quiet eddy in the stream where there is a smooth bottom and an accumulation of dead leaves. In the absence of such eddy and smooth bottom he may be forced to search more diligently among the rocks to secure them. At any rate he soon has a quantity all done up in individual packages which will keep fresh for several days and as he needs them the case is partly removed so as to expose the head, and the crouching victim is pulled forth to repose on the hook in quite a natural position with the head at the

point. If there are any trout or game fish in the stream, this choicest of morsels will not fail to lure them from under the rocks when all man-made baits have failed, especially on the riffles or in swift running water, just where the fish might expect to find an unfortunate separated from his home.

Liberation from the pupal case is effected by a pair of strong mandibles retained from the larval stage expressly for this purpose since they are not carried on into the imago. The adult emerges into the water either from the bottom, from the pupa which swims to the surface, or from the pupa which may crawl upon some object to make a more leisurely appearance.

The ancient ancestors of the caddisflies are thought to have been members of the order *PARAMECOPTERA* taken from the Upper Permian of Belmont, New South Wales, Australia. The *LEPIDOPTERA* are also believed to have arisen from a branch of this archaic group. The earliest known fossil trichopterans are from the European Liassic for which was erected the family *NECROTAULIIDÆ*¹ Handlirsch 1908. Others have been found well represented in Baltic Amber of the Oligocene Tertiary.

The order is well represented throughout the world, there being approximately 3,600 described species to date. Practically all of the members are beneficial in that they form a very important article of diet for fresh-water fish and in some instances check the growth of water weeds

KEY TO FAMILIES² — ADULTS

1. Very small; hairy, moth-like; fore wings with numerous erect clavate hairs, marginal fringe longer than the greatest width; antennæ not longer than fore wings **HYDROPTILIDÆ** p. 414
- Medium to large; wings broad, marginal fringes not so long as the greatest width; antennæ longer than fore wings 2
2. Maxillary palpi five-jointed 3
- Maxillary palpi with less than five joints 14
3. Last joint of maxillary palpi simple and not longer than the other joints 4
- Last joint of the maxillary palpi twisted and imperfectly segmented, usually much longer than the other joints 11
4. Ocelli present 5
- Ocelli absent 7
5. Front tibiæ with two or three spurs; middle tibiæ with four spurs 6
- Front tibiæ with one spur or with none; middle tibiæ with two or three spurs **LIMNephilidæ** p. 415
6. The first two joints of the maxillary palpi short and thick, the third joint much longer and thinner. **RHYACOPHILIDÆ** p. 415
- The second joint of the maxillary palpi much longer than the first **PHRYGANEIDÆ** p. 415

¹ This family contains a number of species taken in Germany, Austria, and England and described in the genera *Necrotaulis* Handlirsch, *Mesotrichopteridium* Handl., *Pseudorthophlebia* Handl., *Trichopteridium* Geinitz, *Paratrichopteridium* Handl., and *Nannotrichopteron* Handl.

² Adapted from J. G. Needham, J. H. Comstock, and others.

7. Principal fork of the median vein in the fore wings without a closed cell 8
Principal fork of the median vein in the fore wings with a closed cell
CALAMOCERATIDÆ p. 416
8. Closed cell in the first fork of the radial sector of the fore wings. 9
No closed cell in the first fork of the radial sector MOLANNIDÆ p. 416
9. Both branches of the radial sector forked 10
Only the anterior branch of the radial sector forked LEPTOCERIDÆ p. 416
10. Veins R_1 and R_2 in the fore wings confluent apically or connected by an apical cross vein ODONTOCERIDÆ p. 416
Veins R_1 and R_2 in the fore wings not connected apically
SERICOSTOMATIDÆ p. 417
11. Ocelli present PHILOPOTAMIDÆ¹ p. 418
Ocelli absent 12
12. Front tibiae with three spurs POLYCENTROPIDÆ p. 418
Front tibiae with less than three spurs 13
13. Anterior branch of radial sector in fore wings forked HYDROPSYCHIDÆ p. 419
Anterior branch of radial sector in fore wings not forked PSYCHOMYIIDÆ p. 419
14. Maxillary palpi with four joints PHRYGANEIDÆ p. 415
Maxillary palpi with two or three joints 15
15. Maxillary palpi filiform and smooth; fore tibiae with a single spur.
LIMNIPHILIDÆ p. 415
Maxillary palpi hairy or scaly; fore tibiae with two spurs.
SERICOSTOMATIDÆ p. 417

LARVÆ²

1. Anal prolegs not fused in median line to form an apparent tenth abdominal segment. 2
Anal prolegs fused in median line to form an apparent tenth abdominal segment 7
2. Abdomen much wider than thorax HYDROPTILIDÆ p. 414
Abdomen little wider than thorax 3
3. Dorsum of ninth abdominal segment with a chitinous shield
REHYACOPHILIDÆ p. 415
Dorsum of ninth abdominal segment without a chitinous shield 4
4. Tracheal gills present HYDROPSYCHIDÆ p. 419
Tracheal gills absent 5
5. Labrum wholly membranous, white PHILOPOTAMIDÆ p. 418
Labrum wholly chitinated 6
6. Frons normal PSYCHOMYIIDÆ p. 419
Frons long, extending to caudal margin of head POLYCENTROPIDÆ p. 418

¹ The family STENOPSYCHIDÆ Martynov 1924, including some of the most beautiful caddisflies, is related to the above, being separated by having the anal angle of the hind wings much wider than the fore wings, the mandibles robust; and the second segment of the maxillary palpi short. The claws of the larvæ are short, curved, and have a single basal spur. Genera referred to here are: *Stenopsyche* McLachlan (Indo-Malaysian), *Parastenopsyche* Martynov (Palæarctic), *Pseudostenopsyche* Döhler (Neotropical), and *Stenopsychodes* Ulmer (Australian). The males of the last named genus have the labrum elongated into the form of a slender rostrum. The larvæ inhabit swift mountain streams.

² Adapted from T. J. Lloyd, J. H. Comstock, and others.

- | | | |
|--|------------------------|--------|
| 7. Dorsal surface of labrum with a row of 20 or more stout bristles | CALAMOCERATIDÆ | p. 416 |
| Dorsal surface of labrum without these stout bristles | 8 | |
| 8. Labrum much longer than broad | ODONTOCERIDÆ | p. 416 |
| Labrum broader than long | 9 | |
| 9. Metanotum with three pairs of chitinized plates | LIMNEPHILIDÆ | p. 415 |
| Metanotum without chitinized plates (present in most SERICOSTO-
MATIDÆ) | 10 | |
| 10. Mesonotum soft or with a pair of minute chitinized plates | PHRYGANEIDÆ | p. 415 |
| Mesonotum wholly chitinized | 11 | |
| 11. Femur of hind legs apparently divided into two segments | LEPTOCERIDÆ | p. 416 |
| Femur of hind legs not divided | 12 | |
| 12. Larval cases made of fine grains of sand and with an extension on each
side and a dorsal head | MOLANNIDÆ | p. 416 |
| Larval cases variable, not as above | SERICOSTOMATIDÆ | p. 417 |

Family HYDROPTILIDÆ Stephens 1836 (Hy'dro-ptil'i-dæ, from the Greek ὕδωρ, water, + πτίλα, wings of insects, feathers). Micro-caddisflies.

The members of this family are the smallest caddisflies. They resemble certain tineid moths and their fringed wings are mostly folded flat over the



FIG. 146. A caddisfly larva in a pebble-covered silken case.
(From *Insects of Western North America*.)

back in repose. The labial palpi are drooping. The adults congregate on the plants overhanging the water and are attracted in great numbers to lights. The larvæ have short legs and distended abdomen and are without respiratory gill tufts. They construct cases of varying forms, bean-shaped or flask-shaped, which are usually parchment-like made only of the silky secretion or also ornamented exteriorly with green algæ, sand, sticks, or other foreign bodies. The cases are open at both ends and are dragged about on edge, being fastened to a support prior to pupation. *Ithytrichia confusa* Morton attaches its tiny limpet-shaped cases to the sides of submerged rocks in running water. The larvæ are able to turn around inside the case. They feed on algæ. The enlarged abdominal segments are much larger than the openings and make it impossible for the larvæ to be carried away by the current. Important genera are: *Hydrop-*

tila Dalman, *Allotrichia* McLachlan, and *Oxyethira* Eaton, all widely distributed and more or less cosmopolitan, and *Mortoniella* Ulmer (Neotropical). *Oxyethira* and *Orthotrichia* Eaton are well represented in North America.

Family LIMNEPHILIDÆ¹ Kolenati 1859 (Lim'ne-phil'-i-dæ, from the Greek λίμνη, lake, marsh, + φίλος, loving).

A large family of some 400 widely distributed species. The females have five-segmented and the males three-segmented maxillary palpi. The females of *Enoicyla* Rambur are apterous, and no males of *Apatania* Kolenati have been collected. The eruciform larvæ have a prosternal tubercle or horn. The majority of species live in quiet and a few in swift water but those of the genus *Enoicyla* live only in damp moss on land. The cases are tubular, straight or curved, the outside ornamented with sticks, tiny shells, sand, and small pebbles. In some species like *Limnephilus combinatus* Walker of Canada the first larval stages construct a log-cabin case in which the sticks are laid across the main axis, and the later stages make new cases ornamented with bits of bark or water snail shells. The larvæ are vegetarians, and the species *Limnephilus flavicornis* Fabricius has been reported by Theobald as a pest of watercress in England. The important genera, *Anabolia* Stephens, *Limnephilus* Leach, *Stenophylax* Kolenati, *Halesus* Stephens, and *Apatania* Kolenati, are all Holarctic. There is, however, at least one South American representative.

Family RHYACOPHILIDÆ Stephens 1836 (Rhy'ac-o-phil'-i-dæ, from the Greek ῥυαξ, stream, torrent, + φίλος, loving). Primitive Caddisflies.

These are the most primitive of all living caddisflies. The campodeiform larvæ have tracheal gills and either crawl about freely among the stones or live in swift streams in loose silken galleries lined exteriorly with small pebbles and attached to rocks. The two common species, *Rhyacophila fuscula* Walker and *Glossosoma americana* Banks, represent these two types. The pupæ are enveloped in a cocoon outside or within the galleries or cases. The important genera are: *Rhyacophila* Pictet, *Glossosoma* Curtis, and *Agapetus* Curtis (Holarctic), *Hydrobiosis* McLachlan, and *Psilochorema* McL. (Australian).

Family PHRYGANEIDÆ² Burmeister 1839 (Phryg'a-ne'-i-dæ, from the Greek φρύγανον, a dry stick). Macro-caddisflies.

These are the largest caddisflies. The maxillary palpi of the females are five-segmented and those of the males are three- or four-segmented. The eruciform larvæ live in still or slowly running water and construct cylindrical cases of bits of leaves and sticks, placed side by side in a series of rings or arranged in a spiral. *Neuronia semifasciata* Say, one of the largest and finest North American species, lives in bogs and swamps. Some members of this genus, when ready to pupate, seek crevices in rocks and bark or burrow into logs or

¹ Also spelled *Limnophilus* and LIMNOPHILIDÆ.

² Some modern authors relegate all of the caddisflies to the single family PHRYGANEIDÆ, which is divided into tribes and subfamilies. The latter correspond to the families in the present arrangement.

even into the hard bottom of watercourses, if available. The important genera *Neuronia* Leach, *Phryganea* Linn., and *Agrypnia* Curtis are all Holarctic.

Family CALAMOCERATIDÆ McLachlan 1877 (Cal'a-mo-cer-at'i-dæ, from the Greek *καλᾶμος*, a reed, + *κέρας*, horn; from the type of larval case).

A small family of caddisflies whose larvæ inhabit still or rapid water and construct cylindrical and subcylindrical cases lined with sand, pebbles, or debris. *Ganonema americana* Walker of Georgia, according to Lloyd (1921), occurs in alder-bordered streams, and the larvæ bore holes through small bits of wood which are then lined with silk and utilized as portable cases.

Family MOLANNIDÆ Wallengren 1891 (Mo-lan'ni-dæ, from the Latin *mola*, a millstone).

A rather small family the known larvæ of which live on the sandy bottoms of streams and lakes and construct shield-shaped cases consisting of a central cylindrical chamber flanked on each side by an extension. A dorsal anterior hood over the head, together with the sandy exterior finish, gives the occupant complete protective coloration.

Family LEPTOCERIDÆ¹ Leach 1817 (Lep'to-cer'i-dæ, from the Greek *λεπτός*, delicate, small, thin, + *κέρας*, horn). Long-horned Caddisflies.

A large family of widely distributed caddisflies in which the body is densely hairy and the antennæ excessively developed, sometimes several times as long as the body, especially in the males. The larvæ are very closely related to the campodeiform type with anal or rectal gills. They also have a pair of occipital sutures not present in other families in the order. They may occur in both still and running water and usually construct straight or curved, cylindrical or tapering cases which are naked or lined exteriorly with sand or vegetable debris, sometimes arranged spirally as in the genus *Triaxnodes* McLachlan. The larvæ swim freely with their legs outside the case. They are vegetarians. The larvæ of *Leptocerus ancylus* Vorhies, occurring in the streams of the eastern states, make a cornucopia-shaped case covered with sand whereas those of *Setodes grandis* Banks, which inhabit lakes and ponds along the Atlantic coast, construct straight tapering cylindrical cases, and those of *Mystacides sepulchralis* Walker, living in lakes and streams of the same general region, spin a cylindrical case of sand to which may be attached several long sticks or pine needles.

The important genera are: *Leptocerus* Leach, *Æcetis* McLachlan, and *Setodes* Rambur, all widespread, and *Mystacides* Latr. (Holarctic), *Leptocella* Banks (American), and *Notanatolica* McL. (Indo-Australian).

Family ODONTOCERIDÆ Wallengren 1891 (O-don'to-cer'i-dæ, from the Greek *ὀδούς*, *ὀδόντος*, a tooth, + *κέρας*, horn).

A small family of species widely distributed throughout the continents of the world, excepting Australia. The known larvæ are eruciform and inhabit rather

¹ Leach designated these as the LEPTOCERIDES in 1817.

swift streams. The North American species, *Psilotreta frontalis* Banks of the eastern states, lives on the riffles and constructs a slightly curved cylindrical case covered with sand. Prior to pupation the larvæ congregate in considerable numbers, attach the cases parallel, and close each end with a small pebble

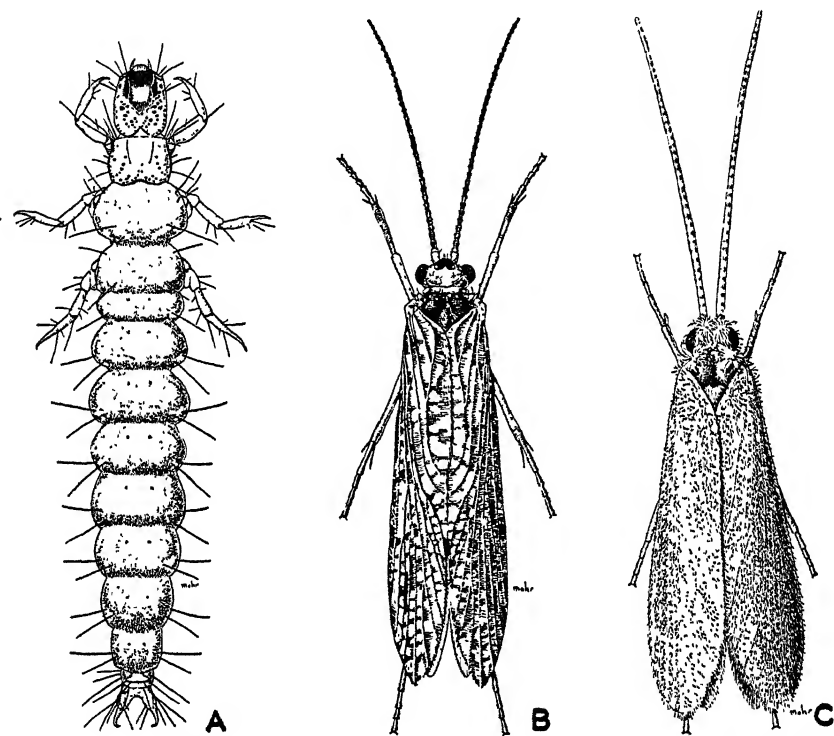


FIG. 147. Caddisflies. A, larva removed from case and B, adult female of *Rhyacophila fenestra* Ross, a common species frequenting the rocky streams of southern Illinois; C, adult *Dolophilus shawnee* Ross also from Illinois. (After Ross, 1938.)

(Lloyd 1921). Important genera are: *Psilotreta* Banks (Holarctic), *Marilia* F. Müller (American), *Odontocerum* Leach (Palæarctic), and *Nerophilus* Banks (North American).

Family SERICOSTOMATIDÆ McLachlan 1876 (Ser'i-co-sto-mat'i-dæ, from the Greek *σηρικός*, silken, + *στόμα*, mouth).

A large and widely distributed family of caddisflies, the antennæ of which are broadly developed at the base with a large hairy scape often longer than the head. The cruciform larvæ live mostly in running fresh water and to a lesser degree in ponds and lakes while one species, listed below, is marine. Tracheal gills are present only in the subfamilies LEPIDOSTOMATINÆ and

GERINÆ. The larvæ usually construct cylindrical cases of sand or of small stones, but many variations in architecture occur. *Helicopsyche borealis* (Hagen) of the eastern United States makes a beautiful snail shell-like case covered with sand. *Gæra calcarata* Banks, inhabiting rocky lake shores and streams of New York State, makes a cylindrical pebble-bedecked case with small flat stones attached to the sides like fins. *Brachycentropus nigrosoma* (Banks), living in the eddies of streams, builds a most unusual square, tapering, chimney-like case of small sticks. The most remarkable member of the family is the marine caddisfly, *Philanisus plebejus* Walker, the larvæ of which construct cases from bits of plant materials and debris and inhabit rocky tidal pools of the ocean along the coasts of Australia and New Zealand. They feed upon coralline seaweeds (Tillyard, 1926). The more important genera are: *Sericostoma* Latr. and *Silo* Curtis (Palæarctic), *Gæra* Leach and *Micrasema* McLachlan (Holarctic), and *Brachycentrus* Curtis and *Helicopsyche* Hagen (widespread).

Family PHILOPOTAMIDÆ McLachlan 1878 (Phil'o-po-tam'i-dæ, from the Greek φίλος, loving, fond of, + ποταμός, a river).

The members of this family constitute a small group of caddisflies in which the last segment of the maxillary palpi is extraordinarily developed in the adults. The campodeiform larvæ are more or less gregarious and often live in great numbers in swift mountain streams where they construct net-like cases in the form of either loose cylindrical tubes or broad sacks. The nets are attached at the end with the larger opening and are distended by the current which carries bits of organic food against the meshes where it is utilized as food by the inhabitant. *Philopotamus ludificatus* McLachlan and *P. montanus* Donovan occur in great numbers in middle Europe. *Chimarra aterrima* Hagen of the eastern United States builds a series of cylindrical silken nets on stones, often in such numbers as almost to cover the surface. Prior to pupating the larva builds a rough shelter of stones and encloses itself in a cocoon.

Important genera are: *Philopotamus* Leach (Holarctic), *Dolophilus* McL. (Holarctic and Australian), *Wormaldia* McL. and *Chimarra* Leach (cosmopolitan).

Family POLYCENTROPIDÆ Ulmer 1906 (Pol'y-cen-trop'i-dæ, from the Greek πολύς, many, + κέντρον, spur; referring to the tibial spurs).

A medium-sized family of widely distributed caddisflies in which the two basal antennal segments are much enlarged and the maxillary palpi are five-segmented in both sexes. The larvæ are campodeiform, have no gills, and live in loosely spun catching nets or in subterranean silk-lined burrows in the bottoms. They inhabit both still and running water but prefer the latter and are thought to be mostly or wholly carnivorous, feeding upon *Cladocera*, *Ostracoda*, or plankton, and small aquatic insect larvæ captured in the nets and among the vegetation and debris. The catching nets are of many forms. *Neureclipsis bimaculata* (Linnæus) of middle and northern Europe constructs

trumpet-shaped nets. *Plectrocnemia conspersa* Curtis of Europe makes large flat catching nets. *Polycentropus flavomaculatus* Pictet, which occurs throughout Europe, builds cup-shaped nets likened to swallows' nests. *Cyrnus flavidus* McLachlan of northern Europe makes funnel-shaped nets attached just under the surface to water plants growing in lakes.

The important genera are: *Polycentropus* Banks and *Plectrocnemia* Stephens (Holarctic and Oriental), *Cyrnus* Stephens (Holarctic and Neotropical), *Neureclipsis* McL. (Holarctic), *Polyplectropus* Ulmer (Neotropical, Oriental, and Australian), and *Dipseudopsis* Walker (Oriental and Ethiopian).

Family HYDROPSYCHIDÆ¹ Curtis 1835 (Hy'dro-psy'chi-dæ, from the Greek ὕδωρ, water, + ψυχή, a butterfly or moth). Seine-making Caddisflies.

A large family well represented throughout much of the world. The adults have two spurs on the fore tibiae and four each on the middle and hind tibiae, and the hind wings have a well-developed anal area. The campodeiform larvæ have numerous gill tufts and live in streams, lakes, and ponds, but are most often encountered in running water. They are often gregarious and do not make portable cases, but rather spin loose silken nets, usually in crevices of stones, to capture small aquatic animal and plant life which may be utilized for food, the members appearing to be both carnivorous and herbivorous. Some of the nets of *Hydropsyche* in particular are exquisitely fashioned. *Macronema zebratum* Hagen is a fine spotted and banded yellowish-brown species in eastern North America from Virginia to Canada. In the snowflake caddisflies belonging to the genus *Smicridea* of Australia and Tasmania the males have white wings and appear in such numbers as to resemble clouds of snowflakes. Among the important genera are: *Hydropsyche* Pictet, *Macronema* Pictet, and *Hydropsychodes* Ulmer (all cosmopolitan), *Diplectrona* Westwood (Holarctic), and *Smicridea* McLachlan (American and Australian).

Family PSYCHOMYIIDÆ Kolenati 1859 (Psy'cho-myi'i-dæ, from the Greek ψυχή, a butterfly, + μυία, a fly).

A small family of caddisflies in which the campodeiform larvæ live in passageways. Some spin catching nets similar to those of the preceding family. They inhabit chiefly rapid or running water but occur also in ponds and lakes. The important genera are: *Psychomyia* Latr. and *Tinodes* Leach (Holarctic), *Lype* McL. and *Metalype* Klapálek (Palæarctic), and *Ecnomus* McL. (Indo-Australian).

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¹ According to earlier workers, this family name was applied to the present HYDROPSYCHIDÆ, PHILOPOTAMIDÆ, POLYCENTROPIDÆ, and PSYCHOMYIIDÆ (Comstock 1924).

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CHAPTER XXXI

28. Order LEPIDOPTERA Linnæus 1758

(Lep'i-dop'ter-a, from the Greek *λεπίς*, *λεπίδος*, scale, + *πτερά*, wings; referring to the scaly wings of these insects.)¹

German, Schmetterlinge, Motten. French, Papillons.

Moths and Butterflies.

Adults medium to large; familiar flying terrestrial insects characterized chiefly by presence of flat overlapping scales and hairs which usually completely clothe the bodies, wings, and other appendages; with complex metamorphosis; sucking mouth parts and conspicuous, long, coiled proboscis; compound eyes large; ocelli two or absent; antennæ variable, often clavate or serrate, hooked or knobbed, or plumose in the males; forelegs normal or reduced. Wings present, usually well developed; rarely vestigial; two pairs, fore pair often largest; with many branched longitudinal and few cross veins; membranous, covered with various kinds of scales and hairs. Somber or intricately and beautifully colored. Larvæ of caterpillars terrestrial; peripneustic; eruciform; smooth, hairy or spiny; mandibulate mouth parts; normally with three pairs thoracic legs and two to four pairs abdominal prolegs; rarely apodous; mostly phytophagous. Pupæ free or obtectate; chrysalis usually suspended or girdled; other forms in silken cocoons or in cells; at least the posterior segments movable.

EXTERNAL ANATOMY — ADULTS

Size — small to large; wing expanse from 5–150 mm.; considering wing area, certain moths are the largest insects in existence.

Shape — bodies somewhat elongate — cylindrical, wings flat and narrow or wide, giving a flattened aspect to the whole insect.

Integument — soft, delicate, fragile, or hard and parchment-like.

Vestiture — entire bodies and usually the wings covered with hairs and scales.

Colors — from somber or cryptic in many forms, especially among the moths, to brilliant colors and combinations of metallic iridescent greens, blues, bronzes, coppers, gold, and silver. Some colors are due to pigments and others to diffraction and interference of light, these latter being more or less permanent.

Head — relatively small, hypognathous, globular or hemispherical, free with small neck, largely covered by eyes.

Antennæ — arise between the eyes; scaly; slender; simple or pectinate; clavate; hooked or knobbed at apices (in most butterflies — RHOPALOCERA); number of segments variable; slightly plumose in some female and wholly plumed in many male moths.

¹ The Greeks referred to these insects as *Psyche* (*ψυχή*, the soul, a spirit), and this word has always been intimately associated with the insects of this order.

Eyes — large, globular, or elongated; separated.

Ocelli — usually two, situated close behind the eyes; often concealed by hairs and scales; or absent.

Mouth parts — suctorial; mandibulate in MICROPTERYGIDÆ; with prominent coiled proboscis. *Clypeus* — small or large median frontal plate. *Labrum* — small, short or narrow triangular plate. *Genæ* — narrow. *Mandibles* — usually wholly absent or microscopically rudimentary. *Proboscis* — formed by the modified galea of the maxillæ, which are greatly elongated with a small semicircular longitudinal groove on inner surface of each, superimposed and locked to form a sucking tube of three channels; sometimes with denticles at tips to puncture plant cells; ringed and coiled like watch spring under thorax at rest; sometimes very long, up to 20 in.; vestigial and functionless in certain moths; *Maxillary palpi* — often prominent, five- to six-segmented when most fully developed; folded (TINEIDÆ and related families); absent, or abbreviated to two or three segments (NOCTUIDÆ); one-segmented (SPHINGIDÆ, GEOMETRIDÆ, PAPILIONIDÆ). *Labium* — reduced to small plate. *Labial palpi* — reduced or well developed, conspicuous, usually three-segmented in butterflies. Hypopharynx present.

Thorax — well developed, segments fused; the venter being called the *pectus*.

Prothorax — normal in lower forms and reduced to a narrow collar in higher groups; with *patagia*, or dorso-lateral sclerites which are directed backwards, well developed in some genera.

Mesothorax — largest. *Metathorax* — of same size or smaller than mesothorax, with scaly posteriorly directed sclerites or *tegulæ* over the bases of the primaries.

Wings (see also same in section on External Anatomy) — normally two pairs, well developed; rarely vestigial and useless; fore pair or primaries usually larger than the second pair or secondaries; membranous, clothed with hairs and overlapping scales, and also *macrotrichia* (and rarely *microtrichia*) or minute hairs, and *androconia* or gland scales in some males (PIERIDÆ and NYMPHALIDÆ); veins strong, many longitudinal and few cross veins, branching, venation similar in primaries and secondaries in some forms, different in most families; usually held erect, horizontally, or roof-like at rest. *Scales* — variable in form, thin and flat hollow sacs strengthened by minute striæ and with short pointed pedicel engaging minute puncture in wing membrane; plain, striated, often iridescent and beautiful. They occur in quantities in plankton, indicating that they are scattered far and wide by the butterflies and moths. *Wing couplings* that hold the two pairs of wings together in flight are: *jugum* (*jugal lobe*), a lobe supporting a number of sensory bristles on the anal area of the primaries, projecting backwards to engage the frenulum; *frenulum* (*humeral lobe*), a lobe bearing sensory bristles on the humeral angle of the secondaries, projecting forward to engage the jugum; or strong chitinous hooks on the subcostal vein of the secondaries in certain males and fewer females which

engage the *reticulum* or group of stiff scales and hairs at the base of the primaries. Species are said to be *jugofrenate* (MICROPTERYGIDÆ) when the *jugal lobe* of the primaries engage the *frenulum* of the secondaries and *frenate* when the bristles (1-9) of the primaries engage the *reticulum* of the secondaries. Both types may be present in many forms. The *frenulum* is absent in the families PROTOTHEORIDÆ, HEPIALIDÆ, LASIOCAMPIDÆ, SATURNIIDÆ, and PAPILIONIDÆ. In these the humeral lobe of the secondaries may extend forwards beneath the primaries and with the aid of the veins and scales serve to lock the wings together in flight. Scent patches appear on the secondaries of a few NYMPHALIDÆ.

Legs — usually well developed, fore pair reduced in NYMPHALIDÆ; all atrophied in female PSYCHIDÆ; clothed with hairs, scales, spines. *Coxæ* large, mostly fixed. *Trochanters* — very small. *Tibiæ* — short, fore pair with a strigil or *epiphysis* consisting of a spur covering an excavation like the antenna cleaner in HYMENOPTERA; posterior tibiæ, and rarely the middle also, with scent-producing organs in males; spurs usually 0-2-4; rarely 0-2-2, or absent. *Tarsi* five segmented; first longest and swollen in some males in LYCÆNIDÆ.

Claws — one pair, simple in most families, cleft or bifid in PIERIDÆ.

Spiracles — one pair between pro- and mesothorax.

Abdomen — 10-segmented in the males (and females of MICROPTERYGIDÆ); segments IX and X of females fused together and forming complicated genitalia.

Male — Segment IX chitinized and referred to as the *tegumen*; other parts of the male genitalia are referred to as *uncus*, *gnathos*, *scaphium*, *manica*, *penis*, *penisfilum*, *harpes* (*harpé*), *gonocoxites* (*valves* or *claspers*), and *saccus*. These organs are extensively used in classifying, especially the moths. The anus is on segment X. A scent brush may be present at the tip of the abdomen (DANAIDÆ).

Female — segments IX and X fused; segments VIII to X often telescopic and forming a retractile ovipositor, the ovipositor being chitinized in a few instances; principal organs represented are *anus*, *gonopore* (with *cloaca* in primitive groups), and *copulatory aperture* (in higher groups). A *tympanum* may be present on the sides of segment I near the first pair of abdominal spiracles.

Spiracles — present on segments I to VIII, inclusive.

Sexual dimorphism — common and at times striking, consisting in the males being more brilliant in color, smaller, and often with plumose antennæ.

Seasonal dimorphism — characteristic of many butterflies and is manifested by: (1) later generations differing in color from the first spring brood; (2) variation due to temperature; (3) changes due to humidity; those insects produced during the wet season are likely to be cryptic and dull-colored; (4) changes due to differences in food.

Mimicry — pronounced in many species in this order. It assumes two common types: (1) *Batesian mimicry* or the mimicry of a distasteful species by an

edible one, (2) *Müllerian mimicry* in which two or more distasteful species mimic each other so that the benefits formerly held by each might be more or less evenly enjoyed by all the members of both. Both of these types may be classed as purposeful mimicry. Other types which are difficult to define in so small a space also occur in nature.

Eggs — among the marvels of biology because of their innumerable sizes, shapes, sculpturings, colors, designs, and arrangements. Usually with tough, hard shells. *Form* — spherical, subglobular, flattened or disk-like, conical, hemispherical, cylindrical, ovoid, fusiform, barrel-shaped, angular, and innumerable other types. *Surface* — smooth and shining or variously traced and sculptured; ribbed, striated, punctured, reticulated, tuberculate, and otherwise ornamented. *Covering* — sometimes covered with silk, cement, and hairs from the body of the female or deposited within a matrix of cement which serves to protect them through the winter. *Colors* — green, white, and yellow predominating, but also brown, red, blue, purple, and various combinations; sometimes brilliant and metallic; more often cryptic or spotted. *Microphyle*, or microscopic opening for the entrance of the sperm — present. In some species a lid is formed which is pushed off by the emerging caterpillar. *Laid* — singly, scattered, in rows, regular, or irregular masses, short suspended chains, in matrices of cement, and in other ways; usually attached to the host but may be deposited indiscriminately by some species in the vicinity of the host.

EXTERNAL ANATOMY — LARVÆ

Size — minute, from 3–5 mm. up to the large sphinx caterpillars, 130–150 mm. in length. Others may be shorter, more robust, and therefore bulkier and heavier.

Shape — usually elongate-cylindrical, slender or robust; some very short and oval; leaf miners decidedly flattened and elongated. Certain forms resemble twigs to a remarkable degree.

Colors — predominately green or otherwise cryptic; many are brightly ornamented and may have a wide variety of patterns and unique designs. Some pass through a series of color patterns and others have different color phases.

Surface and vestiture — very many are naked, smooth or wrinkled, and with indistinct setæ; others are hairy and spiny, some having compound spines (*verrucae* and *scoli*) in a wide variety of arrangements; hairs and spines often stinging and nettle-like; naked or spined tubercles and processes may also be present. Hollow poisonous glandular hairs occur in a few species.

Integument — thin, elastic, sometimes very delicate, or tough, leathery and partly chitinized; composed of head, three thoracic, and 13 body segments.

Head — usually hypognathous; prominent; hard, chitinous, smooth or with horn-like projections; globular, conical, hemispherical, bilobed; free and readily mobile; with *adfrontal areas* (narrow sclerites along the epicranial suture).

Eyes — simple, microscopic, arranged in from two to six pairs on each side of the head.

Antennæ — minute, three-segmented.

Mouth parts — mandibulate for biting, chewing, and burrowing. *Clypeus* — narrow. *Labium* — simple or notched. *Mandibles* — strong, normally toothed. *Maxillæ* — well developed; *palpi* — two-segmented. *Labium* — with spinneret, a short spine or horn-like projection near the end for spinning silk.

Thorax — distinctly three-segmented. Pronotum with forked protrusible repugnatorial gland or *osmeteria* in PAPILIONIDÆ. Prosternal or ventral gland present in NYMPHALIDÆ and in some NOCTUIDÆ and NOTODONTIDÆ.

Legs — one pair of true legs on each of the three thoracic segments; claws single.

Spiracles — large, one pair on prothorax.

Abdomen — normally 10-segmented and cylindrical.

Prolegs — number variable, mostly from two to five pairs, sometimes only terminal pair present; rarely absent; equipped with *crochets* or small sharp hooks in rows or circles at apices for clinging; anal pair often referred to as anal prolegs or anal claspers. A permanent or deciduous dorsal anal horn or scar is present in the SPHINGIDÆ.

Spiracles — eight pairs arranged along the sides and often ornamented with conspicuous, brightly colored spots or other markings.

Repugnatorial glands — may also be present on the dorsum of segments VI and VII in LYMANTRIIDÆ and only on VII in LYCÆNIDÆ.

Chætotaxy — or the study of the arrangement and names of the setæ and bristles on the body, plays an important part in determining the species of the caterpillars. The setæ are classed as primary (12 in the first instar) and subprimary (four additional in the second instar). (For nomenclature and arrangement see S. B. Fracker, *Illinois Biol. Mon.* II, no. 1, 195 pp., 10 pls., 1915.)

Pupæ — variable in form, sculpturing, color, and character of integument. Protected in silken cocoons, either singly or in compact masses, spun by the larvæ; in burrows lined or plugged with silk; in earthen cells in the soil, in cases and tubes formed by the larvæ, attached posteriorly by a silken pad and hanging head downwards (NYMPHALIDÆ); or attached by posterior pad and silken thoracic girdle in a vertical, inclined, or horizontal position with the head usually up (PIERIDÆ, PAPILIONIDÆ).

Types: (1) *Libera* or *free* — with soft integument, functional mandibles, and the appendages loose and free, mobile (MICROPTERYGIDÆ and related primitive families). (2) *Incompleta* — with leathery or hard integument; without mandibles, appendages partly free, but sheathed, mobile to the extent of leaving cocoon or burrow before the adult emerges (HEPIALIDÆ and many lower families). (3) *Obtecta* or *chrysalis* — with leathery or hard integument, without mandibles; appendages completely

sheathed with body and cemented down; rigid and immobile excepting the apical abdominal segments; frequently attached by the *cremaster*, an anal spine, hooks, or processes, or a pad, or by a pad and girdle.

The habits and life histories of butterflies and moths are so varied as to be beyond the scope of this paper. Suffice it to say that only a relatively very few complete life history studies have been made and there is yet much to be done in this important field. Adult butterflies and moths are among the most delightful and pleasing objects of nature and have long been of great interest and concern to mankind. The caterpillars of many species are harmful in the sense that they feed upon certain economic plants which through untold ages have been theirs, plants which man has set apart for his own exclusive use during his brief but dominant reign over nature. Only in unconquered tropical forests, desert wastes, and useless swamps are these remarkable insects permitted to perform their destinies without hindrance. But even here commercial hunters are searching out beautiful iridescent species for the ephemeral uses of man to such a degree that complete extermination awaits these beautiful creatures which can never be replaced. To get some appreciation of butterflies and moths, the student is requested to read *The Life of the Butterfly* by Friedrich Schnack, translated by Winifred Katzin (Houghton Mifflin, Boston, 1932), which is written with a style and charm not excelled by any other writer.

While butterflies are largely diurnal and moths crepuscular and nocturnal in habits, these habits are by no means universal, especially in the moths among which there are many day fliers. There is much variation in the range of flight of different genera and families. Many moths are restricted to rather circumscribed areas while butterflies often migrate hundreds and even thousands of miles. The painted lady or thistle butterfly, *Vanessa cardui* (Linn.), holds first place as a migratory species, but the cabbage butterfly, *Pieris rapæ* Linn., and many other species have extensive migratory habits. Among the moths the silver "Y" moth, *Plusia gamma* (Linn.), migrates from the Mediterranean region of northern Africa across Europe. In most continental areas there are more or less distinct seasonal migrations which are marked in many countries. Many such instances could be cited for both butterflies and moths. Adults hibernate and aestivate. Some of the most delicate species like the common European brimstone butterfly or lemon bird, *Gonepteryx rhamni* (Linn.), often lie frozen stiff under the snows of winter whereas the mourning cloak, *Nymphalis antiopa* (Linn.), of Europe and North America seeks more congenial weather in the southern limits of its range and is active most of the winter. The monarch or milkweed butterfly, *Danaus menippe* (Hübner), collects in great numbers on certain trees along the Pacific coast in California during the winter months.

The eggs are laid at various seasons, spring, summer, and autumn. While they are usually attached to the hosts, this is by no means always the case. From a few to a thousand may be laid by a single female. Hatching does not always correspond with emergence of the larvæ, for in many cases the minute fully formed first-instar larvæ remain in the eggshells from midsummer or fall

until early spring, when they may emerge *en masse* in the first spell of warm weather.

Actual hatching may take place in from 2 to 60 days. First-hatched larvæ frequently consume the eggshell for the first meal. Growth is rapid and usually after four or five molts (rarely up to nine) may be completed in from 20 to 90 days. A complete life cycle including all stages, egg to adult, requires from 4 months to 4 years. From one to three broods may occur within a single year.

The larvæ are normally phytophagous, feeding upon all types of living and dead vegetable matter including seeds, stored cereals, museum plant specimens, and other similar products. When confined together, caterpillars often turn cannibalistic, a condition observed in the case of the corn earworm, *Heliothis armigera* (Hübner). The larvæ of a number of butterflies and moths are carnivorous. Clark (*Smiths. Rept.*, pp. 439–508, 1925) lists 12 species of butterflies (LYCÆNIDÆ) which definitely feed upon other insects such as aphids, leafhoppers, treehoppers, coccids, or larvæ of ants. The Australian noctuids, *Eublemma cocciphaga* (Meyrick), and the European *Erastria scitula* (Rambur) as well as the American pyralid, *Lætilia coccidiivora* Comstock, all feed upon unarmored scale insects (COCCIDÆ). A few live on beeswax, others act as scavengers in ants' nests, and the larvæ of *Bradypodicola hahneli* Spuler are said to be ectoparasitic on the three-toed sloths, *Bradypus*, of tropical America.¹ Many species are very serious pests of plants in general as well as of many important agricultural crops. The silk-producing species, including the Chinese silkworm, *Bombyx mori* Linn., and three other notable species, are among the most important wealth-producing domesticated animals.

Caterpillars construct a wide variety of protective devices, other than the ordinary silken cocoons, such as cases and shields in which the larvæ live and in which pupation subsequently takes place. Cocoons are also variable in shape and structure. In certain African moths great masses of closely spun silk may incorporate a large number of individual cocoons or cells in which pupation occurs. Particles of grass, wood, sticks and leaves, hair, and other foreign matter may be incorporated in or on the outside of the cocoons. Calcareous cases, resembling birds' eggs and often beautifully ornamented, are made by tropical slugworms. Cocoons may be single or double, closed or open with a protected exit, variously ornamented in the African *Terphatrix lanaria* Holland with small white balls of silk like the cocoons of certain hymenopterous parasites. Those of the ribbed casemakers, *Bucculatrix*, spp., are surrounded by a palisade of erect strands of silk which may serve as a protection against parasitism. Pupæ escape from the cocoons by tearing the silk with special horns, or by cutting it with the mandibles. Adults escape by secreting chemical solvents which readily dissolve the silk and permit egress or by tearing the cocoon by means of special spines or processes. Butterflies in general and a great many moths do not construct cocoons at all.

The fossil history of the LEPIDOPTERA is brief. The members of this order

¹ It is possible that the larvæ of this interesting moth may feed upon the algæ which often occur abundantly on the hairs of sloths in the moist jungles.

are among the latest insects to appear, and no positive records occur beyond the Tertiary, although Tillyard believes that forms related to the MICROPTERYGIDÆ must have existed in the Lias, the oldest division of the European Jurassic. Butterflies occurred in the Eocene and Oligocene of North America, and small moths have been found in European Oligocene Baltic Amber.

The order is a large one numbering about 105,000 species, 1,000 genera, and 190 families. The species are widely distributed throughout the world. The largest and most beautiful specimens live in the tropics, but many fine species also adorn the temperate regions.

The classification of the order presents so many difficulties that no adequate attempt is made to enter this field. At the present time there is no complete systematic arrangement of suborders, superfamilies, series, and families other than that of Brues and Melander (1932). The writer has had much difficulty in arranging these various categories in proper sequence. In general the families as listed by Brues and Melander and the systems of Brohmer, Ehrmann, and Ulmer (1932) have been used as a basis for the following classification.

CLASSIFICATION

I. Suborder JUGATÆ Comstock 1892 ¹ (HOMONEURA Tillyard 1918)

(1) Superfamily MICROPTERYGOIDEA Dyar 1902

- | | |
|------------------------|--------------------------|
| 1. Family ERIOCRANIIDÆ | 3. Family MICROPTERYGIDÆ |
| 2. " NEOPSEUTIDÆ | (ERIOCEPHALIDÆ) |
| | 4. " MNESARCHÆIDÆ |

(2) Superfamily HEPIALOIDEA Mosher 1916

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|---------------------|-----------------------|
| 5. Family HEPIALIDÆ | 7. Family ANOMOSEPIDÆ |
| 6. " PROTOTHEORIDÆ | 8. " PALÆOSEPIDÆ |

II. Suborder FRENATÆ Comstock 1892 (HETERONEURA Tillyard 1918)

A. Division HETERONEURA Tillyard 1918

(3) Superfamily COSSOIDEA Tillyard 1926

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|--------------------|-------------------------|
| 9. Family COSSIDÆ | 13. Family ARGYROTYPIDÆ |
| 10. " ZEUZERIDÆ | 14. " RATARDIDÆ |
| 11. " ENGYPHLEBIDÆ | 15. " HYPOPTIDÆ |
| 12. " STYGIARIDÆ | |

(4) Superfamily CASTNIOIDEA Handlirsch 1925

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|--------------------------------|
| 16. Family CASTNIIDÆ |
| 17. " TASCINIDÆ (NEOCASTNIIDÆ) |

(5) Superfamily TINEOIDEA ² Dyar 1902

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|--|
| 18. Family COLEOPHORIDÆ (EUPHISTIDÆ, HAPLOPTILIDÆ) |
| 19. " MOMPHIDÆ |

¹ HOMONEURA Tillyard 1918 has been used for this suborder and also for the cockroaches and mantids by Enderlein in 1903.

² It has not always been possible to distinguish among the members of this superfamily, those of the INCURVARIOIDEA, YPONOMEUTOIDEA, and others.

20. Family GRACILARIIDÆ (EUCESTIDÆ, LITHOCOLLETIDÆ)
 21. " PHYLLCENISTIDÆ
 22. " LYONETIIDÆ (BEDELLIIDÆ, BUCCULATRIGIDÆ, ERECH-
 THIIDÆ, HIEROXESTIDÆ)
 23. " TISCHERIIDÆ 29. Family SETOMORPHIDÆ
 24. " CENOPHILIDÆ 30. " TINEIDÆ (MONOPIDÆ)
 25. " TALÆPORIIDÆ 31. " PLUTELLIDÆ
 26. " RIDIASCHINIDÆ 32. " AMYDRIIDÆ
 27. " CECIDOSIDÆ 33. " ARRHENOPHANIDÆ
 28. " ACROLOPHIDÆ 34. " EPIMARTIDÆ

(6) Superfamily NEPTICULOIDEA Forbes 1923

35. Family NEPTICULIDÆ (STIGMELLIDÆ) 35a. Family OPOSTEGIDÆ

(7) Superfamily INCURVARIOIDEA Forbes 1923

36. Family INCURVARIIDÆ (LAMPRONIIDÆ) 38. Family ADELIDÆ
 37. " PRODOXIDÆ

(8) Superfamily YPONOMEUTOIDEA Mosher 1916

39. Family XYLORICTIDÆ (CRYPTOPHASIDÆ, UZUCHIDÆ, SYNTOMIDÆ)
 40. " ARGYRESTHIIDÆ
 41. " GLYPHPTERYGIDÆ (CHOREUTIDÆ, HEMEROPHILIDÆ, SI-
 METHIDÆ)
 42. " ÆGERIIDÆ (SESIIDÆ) 44. Family STREPSIMANIDÆ
 43. " HELIODINIDÆ 45. " ACROLEPIIDÆ
 (TINÆGERIIDÆ) 46. " ASHINAGIDÆ
 47. " YPONOMEUTIDÆ (HYPONOMEUTIDÆ, ATTEVIDÆ, HYPONO-
 TIDÆ, HYPSELOPHIDÆ, ORTHOTÆLIIDÆ)
 48. " SCYTHRIDIDÆ (SCYTHRIDÆ, BUTALIDÆ)

(9) Superfamily GELECHIOIDEA Mosher 1916

49. Family COSMOPTERYGIDÆ (LAVERNIDÆ)
 50. " AMPHITHERIDÆ
 51. " AGONOXENIDÆ
 52. " EPERMENIIDÆ
 53. " HYPOSMOCOMIDÆ
 54. " GELECHIIDÆ (DICHOMERIDÆ)
 55. " ŒCOPHORIDÆ (DEPRESSARIIDÆ)
 56. " BLASTOBASIDÆ
 57. " STENOMIDÆ (STENOMATIDÆ)
 58. " ETHMIIDÆ

(10) Superfamily ELACHISTOIDEA Förster 1856 (CYCNODIOIDEA Forbes 1923)

59. Family HELIOZELIDÆ
 60. " DOUGLASIIDÆ
 61. " ELACHISTIDÆ (APHELOSETHIDÆ, CYCNODIIDÆ, CHRYSO-
 PELEIIDÆ)
 62. " CEMIOSTOMIDÆ

(11) Superfamily TORTRICOIDEA McDunnough 1939

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|------------|---|------------------------|
| 63. Family | OLETHREUTIDÆ (EUCOSMIDÆ, GRAPHOLITHIDÆ) | |
| 64. " | CHLIDANOTIDÆ | |
| 65. " | TORTRICIDÆ (SPARGANOTHIDÆ) | |
| 66. " | PHALONIIDÆ (COMMOPHILIDÆ, CONCHYLIDÆ) | |
| 67. " | CARPOSINIDÆ | 70. Family ANOMOLOGIDÆ |
| 68. " | METACHANDIDÆ | 71. " ATYCHIIDÆ |
| 69. " | CYCLOTORNIDÆ | 72. " OCHSENHEIMERIIDÆ |

(12) Superfamily PTEROPHOROIDEA Tillyard 1926

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|------------|--------------------------|----------------------|
| 73. Family | PTEROPHORIDÆ (ALUCITIDÆ) | 75. Family AGDISTIDÆ |
| 74. " | OXYCHIROTIDÆ | 76. " ORNEODIDÆ |

(13) Superfamily PYRALIDOIDEA Mosher 1916

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|------------|-----------------------|------------------------|
| 77. Family | TINEODIDÆ | 81. Family SCHENOBIIDÆ |
| 78. " | THYRIDIDÆ | 82. " CRAMBIDÆ |
| 79. " | PYRAUSTIDÆ | 83. " GALLERIIDÆ |
| 80. " | PYRALIDIDÆ (PYRALIDÆ) | 84. " PHYCITIDÆ |

(14) Superfamily ZYGÆNOIDEA¹ Gravenhorst 1843

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|------------|--|----------------------------------|
| 85. Family | EUCLEIDÆ (COCHLIOPODIDÆ, COCHLIDIIDÆ, LIMACODIDÆ, HETEROGYNIDÆ, EPICNOPTERYGIDÆ) | |
| 86. " | MEGALOPYGIDÆ (LAGOIDÆ) | 89. Family CHARIDEIDÆ |
| 87. " | DALCERIDÆ (ACRAGIDÆ) | 90. " CHRYSOPOLOMIDÆ (ECTROPIDÆ) |
| 88. " | EPIPYROPIDÆ | |
| 91. " | ZYGÆNIDÆ (ANTHROCERIDÆ, CHALCOSIIDÆ, PYROMORPHIDÆ) | |
| 92. " | HIMANTOPTERIDÆ | |
| 93. " | PSYCHIDÆ | |
| 94. " | TALÆPORIIDÆ (Also in TINEOIDEA of authors) | |
| 95. " | METARBELIDÆ (ARBELIDÆ, TERAGRIDÆ, HOLLANDIDÆ, LEPIDARBELIDÆ) | |

(15) Superfamily NOCTUOIDEA Mosher 1916

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|------------|---|
| 96. Family | AMATIDÆ |
| 97. " | NOLIDÆ |
| 98. " | LITHOSIIDÆ |
| 99. " | EUCHROMIIDÆ (SYNTOMIDÆ, SYNTOMIDIDÆ) |
| 100. " | ARCTIIDÆ |
| 101. " | HYPSIDÆ (AGANIDÆ, ASOTIDÆ, CALLIMORPHIDÆ) |
| 102. " | AGARISTIDÆ |
| 103. " | COCYTIIDÆ (EUCOCYTIIDÆ) |
| 104. " | PHALÆNIDÆ |
| 105. " | PLUSIIDÆ |
| 106. " | NOCTUIDÆ (CARADRINIDÆ) |
| 107. " | HYLOPHILIDÆ |
| 108. " | ANTHELIDÆ |

¹ Certain of the families included in this superfamily are united with the PSYCHIDÆ to form a superfamily PSYCHOIDEA by Tillyard (1925).

109. Family ENDROMIDIDÆ (ENDROMIDÆ)

110. " HYBLÆIDÆ

111. " PERICOPIDÆ

112. " DIOPTIDÆ

113. " NOTODONTIDÆ (CERURIDÆ)

114. " LYMANTRIIDÆ (LIPARIDÆ, LIPARIDIDÆ, OCNERIIDÆ)

(16) Superfamily DREPANOIDEA Forbes 1923

115. Family THYATIRIDÆ (CYMATOPHORIDÆ, POLYPLOCIDÆ, NOCTUO-BOMBYCIDÆ)

116. " DREPANIDÆ (DREPANULIDÆ)

117. " AXIIDÆ

118. " CALLIDULIDÆ

119. " PTEROTHYSANIDÆ

(17) Superfamily URANIOIDEA Forbes 1923

120. Family URANIIDÆ

121. " EPIPLEMIDÆ (EROSIIDÆ)

122. " LACOSOMIDÆ (LACOSOMATIDÆ, MIMALLONIDÆ, PEROPHORIDÆ, PROTOPSYCHIDÆ)

(18) Superfamily SPHINGOIDEA Dyar 1902

123. Family SPHINGIDÆ (SMERINTHIDÆ)

(19) Superfamily GEOMETROIDEA Forbes 1923

124. Family CENOCHROMATIDÆ

125. " GEOMETRIDÆ (BREPHIDÆ, MONOCTENIIDÆ, SELIDOSEMATIDÆ)

126. " BOARMIIDÆ (HEMITHEIDÆ)

127. " EPICOPEIIDÆ

128. " ACIDALIIDÆ (SCOPULIDÆ, STERRHIDÆ)

129. " LARENTIIDÆ (HYDRIOMENIDÆ)

130. " LONOMIIDÆ

(20) Superfamily BOMBYCOIDEA Dyar 1902

131. Family LASIOCAMPIDÆ (LACHNEIDÆ) ¹

132. " THAUMETOPEIDÆ (EUPTEROTIDÆ)

133. " LEMONIIDÆ (CRATERONIDÆ)

134. " BRAHMÆIDÆ

136. Family BOMBYCIDÆ

135. " OXYTENIDÆ

137. " ZANOLIDÆ

(21) Superfamily SATURNIOIDEA Dyar 1902

138. Family SATURNIIDÆ ² (ATTACIDÆ, ARSENURIDÆ, HEMILEUCIDÆ, AGLIIDÆ)

139. " CITHERONIIDÆ (CERATOCAMPIDÆ, SYSSPHINGIDÆ)

140. " CERCOPHANIDÆ

¹ The LASIOCAMPIDÆ are placed in a separate superfamily LASIOCAMPOIDEA by Tillyard (1925).

² The family SATURNIIDÆ is united with BOMBYCIDÆ in the superfamily BOMBYCOIDEA by Tillyard (1925).

B. Division RHOPALOCERA Duméril 1806

(22) Superfamily HESPERIOIDEA Wallengren 1853

141. Family HESPERIIDÆ (ACHLYODIDÆ, CYCLOPIDIDÆ, EUDAMIDÆ,
PYRGIDÆ, TELECONIDÆ, THAMYRIDIDÆ, THYMELIDÆ)
142. " EUSCHEMONIDÆ
143. " MEGATHYRIDÆ

(23) Superfamily PAPILIONOIDEA Dyar 1902

144. Family PAPILIONIDÆ (EQUITIDÆ)
145. " BARONIIDÆ
146. " TEINOPALPIDÆ
147. Family PARNASSIIDÆ
148. " PIERIDÆ (ASCIIDÆ)
149. " DANAIDÆ (ACRÆIDÆ, EUPLEIDÆ, LYMNADIDÆ, MANIO-
LIDÆ)
150. " EUEIDIDÆ (PALÆOTROPIDÆ, HELICONIDÆ)
151. " ITHOMIIDÆ
152. " SATYRIDÆ (AGAPETIDÆ)
153. " BRASSOLIDÆ (CALIGONIDÆ)
154. " MORPHOIDÆ (ARGIDÆ, AMATHUSIIDÆ)
155. " NYMPHALIDÆ (ARGYREIDÆ)
156. " LIBYTHEIDÆ
157. " RIODINIDÆ (ERYCINIDÆ, NEMEOBIIDÆ, PLEBEIIDÆ, RHIO-
DINIDÆ)
158. " LYCÆNIDÆ (CUPIDINIDÆ, RURALIDÆ)

KEY TO LARVÆ OF CERTAIN IMPORTANT FAMILIES¹

1. Thoracic legs wanting or reduced to fleshy swellings, without chitinated segments 2
Thoracic legs developed, with chitinous segments 8
2. Body fusiform, thickest at middle, head small with closed front (separated from the vertex by the epicrania) PRODOXIDÆ
Body cylindrical or flattened, when somewhat fusiform with front reaching vertex 3
3. Head with six small ocelli on each side 4
Head with two ocelli on each side, front not reaching vertex
HELIOZELIDÆ
Head with a single large ocellus on each side, or none 5
4. Abdomen with rudimentary ventral prolegs on third to sixth segments, bearing hooks TISCHERIIDÆ
Abdomen without prolegs on sixth segment. GRACILARIIDÆ p. 447
5. Ocellus frontal, front triangular ERIOCRANIIDÆ
Ocellus lateral, front quadrangular 6
6. Front widest at posterior end, body normally depressed, prolegs on third to fifth segments of abdomen when present . . GRACILARIIDÆ p. 447
Front widest at anterior end, body cylindrical; rudimentary prolegs on second to seventh segments of abdomen or none. 7

¹From W. T. M. FORBES, "The Lepidoptera of New York and Neighboring States," *Cornell Agr. Exp. Sta. Mem.* 68, 1923.

7. Body normal, five times as long as thick, normally with prolegs
 NEPTICULIDÆ p. 448
 Body very slender, 10 times as long as thick, without prolegs
 OPOSTEGIDÆ
8. Setæ replaced by large, ovate scales, arranged in pairs MICROPTERYGIDÆ p. 439
 Setæ normal 9
9. Crochets wanting, prolegs rudimentary or absent 10
 Prolegs at least represented by rudimentary crochets 13
10. Front extending obviously to vertex; small species COLEOPHORIDÆ p. 447
 Front not extending to vertex (except when vertex is represented by a
 very narrow slit) 11
11. Head completely retracted, body frequently with spines or secondary
 hair, the primary setæ obsolete; body with obscure incisures, usually
 with conspicuous pits EUCLEIDÆ p. 469
 Head normally exposed; body with primary setæ only, which are usu-
 ally distinct; with strong incisures 12
12. Setæ IV and V distant on abdomen; prolegs present, though without
 hooks (Tegeticula) PRODOXIDÆ
 Setæ IV and V adjacent; prolegs absent A few GELECHIDÆ p. 457
13. Body without secondary or tufted setæ, tubercle VI single; VII of three
 setæ at most, unless the proleg has a multiserial circle of hooks, when
 it may have four setæ; sometimes with a couple of dorsal subprimary
 setæ 14
 Body with tufted or secondary hair; at least two setæ on tubercle VI on
 sixth segment of abdomen, or with additional setæ on proleg 48
14. Sixth segment of abdomen without a proleg GRACILARIIDÆ p. 447
 Sixth segment of abdomen with a proleg, the more anterior segments
 sometimes without 15
15. Hooks of prolegs arranged in a circle or ellipse (sometimes interrupted)
 or in transverse bands 16
 Hooks of prolegs in a single band, sometimes with a few rudimentary
 outer hooks besides 42
16. Prespiracular wart of prothorax with two setæ 17
 Prespiracular wart of prothorax with three setæ 18
17. Hooks uniordinal, body cylindrical, VII of mesothorax with a single
 seta ORNEODIDÆ
 Hooks biordinal or triordinal, or uniordinal in larvæ with stout fusi-
 form body and bisetose tubercle VII of mesothorax PYRALIDIDÆ p. 465
18. Hooks of prolegs arranged in two transverse bands 19
 Hooks in a circle or ellipse, sometimes broadly interrupted 24
19. Prolegs with two simple series of hooks 20
 Prolegs with a single series of hooks, or with two bands formed of
 several series of alternate hooks INCURVARIIDÆ
20. Setæ IV and V of abdomen remote (Bucculatrix) LYONETIDÆ p. 448
 Setæ IV and V of abdomen adjacent 21
21. Hooks of anal prolegs in two groups GELECHIDÆ p. 457
 Hooks of anal prolegs in a single series 22
22. Front extending about one third way to vertex (Cossula) COSSIDÆ p. 444
 Front extending at least two thirds way to vertex 23

23. Spiracles elliptical, normal in size, those of eighth segment of abdomen higher than the others **ÆGERIIDÆ** p. 452
Spiracles very small, circular, the last pair about in line **COLEOPHORIDÆ** p. 447
24. Setæ iv and v of abdomen remote, or, in a few minute species, v absent 25
Setæ iv and v adjacent, often on a common tubercle, no small hooks at base of principal series on prolegs 30
25. Hooks arranged in a single complete ellipse. 26
Hooks arranged in a broken ellipse, or with additional rudimentary series at the base of the normal ones 28
26. Prothorax with setæ of prespiracular group about as far from spiracle as from each other; seta i on abdomen higher than ii . **LYONETIIDÆ** p. 448
Prothorax with setæ of prespiracular group about twice as far from spiracle as from each other 27
27. Seta i of abdomen, much lower than ii **TINEIDÆ** p. 449
Seta i of abdomen not lower than ii **HELIODINIDÆ** p. 445
28. Mesothorax and metathorax with seta ia in front of ib and well separated, abdomen with iv above level of spiracle **HEPIALIDÆ** p. 439
Mesothorax and metathorax with setæ ia and ib closely associated; abdomen with iv below level of spiracle 29
29. Prothorax with seta beta higher (nearer mid-dorsal line) than alpha **ACROLOPHIDÆ**
Prothorax with seta beta lower than alpha **YPONOMEUTIDÆ** p. 456
30. Last pair of spiracles dorsal, closer together on middle line than setæ i of anterior abdominal segments **CARPOSINIDÆ**
Last pair of spiracles nearly normal 31
31. Mesothorax with two setæ vii (above base of leg). 32
Mesothorax with a single seta vii; ninth abdominal segment with seta ii higher than i 33
32. Prothoracic spiracle with long axis vertical; ninth abdominal segment with seta i higher than ii **THYRIDIDÆ**
Prothoracic spiracle with long axis horizontal **PSYCHIDÆ** p. 470
33. Setæ ii of ninth abdominal segment closer together than on any other, frequently on the same plate 34
Setæ ii of ninth abdominal segment as far apart as on the other segments, very rarely (*Zeusera*) on the same plate 35
34. Abdomen with setæ iv and v practically horizontally placed; hooks of prolegs uniordinal **PHALONIIDÆ**
Abdomen with setæ iv and v in a diagonal or vertical line; hooks usually multiordinal **TORTRICIDÆ** p. 462
35. Coxæ of metathoracic legs twice as far apart as wide; prolegs small; small species **COSMOPTERYGIDÆ**
Coxæ of metathoracic legs closer together 36
36. Setæ i and ii adjacent on abdominal segments
(*Schreckensteinia*) **HELIODINIDÆ** p. 455
Setæ i and ii widely separated 37
37. Front reaching less than half way to vertex (about half way in some very large species with horizontal head and triordinal hooks) 38
Front reaching two thirds way to vertex or a little shorter, and ending

- in an attenuate point; small species with uniordinal or biordinal hooks 39
38. Borers; abdomen with setæ iv and v on separate tubercles on the ninth segment COSSIDÆ p. 444
 Leaf feeders; abdomen with setæ iv and v on the same tubercle on the ninth segment (*Stenoma*) XYLORICTIDÆ
39. Hooks of prolegs biordinal 40
 Hooks of prolegs uniordinal 41
40. Second, third, and fourth ocelli grouped together, more widely separated from first and lower CECOPHORIDÆ
 Ocelli evenly spaced GELECHIIDÆ p. 457
41. Abdomen with seta III farther back than spiracle on eighth segment BLASTOBASIDÆ
 Abdomen with seta III not farther caudad than spiracle GLYPHIPTERYGIDÆ
42. Prespiracular wart on prothorax with three setæ 43
 Prespiracular wart on prothorax with two setæ 44
43. Setæ iv and v of abdomen remote; or, if approximate, setæ *beta* much closer together than setæ *alpha* on prothorax and prolegs long and slender YPONOMEUTIDÆ p. 456
 Setæ iv and v close together; *beta* about as far apart as *alpha*; prolegs usually short (*Ethmia*) ETHMIIDÆ
44. Tubercle VII on mesothorax and metathorax with two setæ 45
 Tubercle VII on mesothorax and metathorax with a single seta 47
45. Setæ minute, tubercles reduced to obscure rings, head unusually wide, and prolegs reduced THYATIRIDÆ
 Setæ heavy, almost always spinulose, on conspicuous tubercles 46
46. Tubercle III of abdomen with two setæ LITHOSIIDÆ
 Seta III of abdomen single (*Utelheisa*) ARCTIIDÆ p. 472
47. North American species with enlarged, contrasting tubercles; and a hump on eighth segment of abdomen; contrastingly striped transversely (or spotted) with black AGARISTIDÆ p. 477
 Caterpillars of other types NOCTUIDÆ p. 475
48. Larvæ with less than the normal number of ventral prolegs; or with the first pair of ventrals much reduced 49
 Larvæ with the normal four pairs of ventral prolegs; the anals sometimes reduced 50
 Larvæ with additional prolegs without hooks MEGALOPYGIDÆ
49. Hair tufted; hooks of prolegs uniordinal; 14 legs. NOLIDÆ
 With a few subprimary hairs only (in some exotic species with fine secondary hair), sometimes with only a single subventral subprimary on sixth segment of abdomen; usually 10 legs GEOMETRIDÆ p. 484
50. Anal prolegs wholly lost DREPANIDÆ
 Anal prolegs represented by a pair of large tubercles, or flagella at least, normally fully developed. 51
51. Hooks of prolegs uniordinal 52
 Hooks of prolegs biordinal or triordinal 66
52. Warts rudimentary or absent, or obscured by secondary hair 53

- At least wart VI (subventral) many-haired and distinct, secondary hairs sparse or absent above prolegs 60
53. Anal plate bifurcated, head roughly papillose; third ocellus very large SATYRIDÆ p. 510
- Anal plate simple; head smoother; third ocellus rarely much enlarged 54
54. Larva parasitic, with hemispherical body and a complete circle of uniordinal hooks EPIPYROPIDÆ
- Larva more normal in shape, not parasitic 55
55. Spiracles small, circular, ventral prolegs slender, more or less stem-like, with expanded planta PTEROPHORIDÆ p. 463
- Spiracles elliptical, larger; ventral prolegs short 56
56. Secondary setæ dense 57
- Secondary setæ very sparse or absent above prolegs; with simple setæ or a few subprimaries 58
57. Notch of labrum deep, with parallel sides; anal prolegs full as strong as the others; with warts more or less overshadowed by the secondary hair A few NOCTUIDÆ p. 475
- Notch acute, with convergent sides; anal prolegs much reduced and not used; warts rudimentary and dominated by a single hair (*Melalopha*) or absent (*Datana*) NOTODONTIDÆ p. 477
58. Tubercle IV at about the same level on abdominal segments VI, VII, and VIII (Doa) LYMANTRIDÆ p. 478
- Tubercle IV much lower on seventh than on other segments; anal prolegs more or less reduced or modified 59
59. Skin shagreened DIOPTIDÆ
- Skin not shagreened Most NOTODONTIDÆ p. 477
60. Eversible mid-dorsal glands on two segments of abdomen LYMANTRIDÆ p. 478
- No eversion dorsal glands 61
61. Spiracles circular, small 62
- Spiracles elliptical, normal in size 63
62. Ventral prolegs short, with a straight band of heavy hooks PYROMORPHIDÆ
- Ventral prolegs slender, with an expanded planta sometimes bearing a circle of hooks PTEROPHORIDÆ p. 463
63. Mesothorax with only a single large wart above level of spiracles EUCHROMIIDÆ
- Mesothorax with two or three warts above level of spiracles 64
64. Wart (or seta) IV at about the same level on seventh abdominal segment as on the sixth and eighth ARCTIIDÆ p. 472
- Wart (or seta) IV much lower on seventh segment or absent (perhaps fused with v) 65
65. Hooks of prolegs even in length, or gradually becoming smaller at ends of row A few NOCTUIDÆ p. 475
- Hooks of prolegs abruptly decreasing in size near each end PERICOPIDÆ
66. Body without general secondary hair, often with a few subprimaries; with not more than eight hairs on prolegs 67
- Body with numerous secondary setæ, at least on the prolegs; anal prolegs always well developed 72

67. Hooks in a complete circle. 68
 Prolegs with a band of hooks on inner side, sometimes supplemented
 with a much weaker band on outer side 70
68. Subdorsal setæ of abdomen represented by warts
 (*Scythris*) **YPONOMEUTIDÆ** p. 456
 Subdorsal setæ of abdomen simple 69
69. Head rugose, body widest at proleg-bearing segments. **LACOSOMIDÆ**
 Head smooth, body widest at first segment of abdomen
 (*Ptochoryctis*) **XYLORICTIDÆ**
70. Prespiracular wart of prothorax with three setæ; setæ IV and V of
 abdomen approximate. (*Ethmia*) **ETHMIIDÆ**
 Prespiracular wart of prothorax with two setæ; setæ IV and V of
 abdomen usually distant 71
71. First and last spiracles twice as large as the others . **EPIPLEMIDÆ**
 Spiracles subequal **THYATRIDÆ** p. 486
72. Setæ very irregular in length, some 10 times as long as others; with
 obscure warts, at least in younger stages, sometimes with spatulate
 scale hairs. 73
 Setæ subequal or supplemented by prominent warts or by spines 74
73. Labrum notched two thirds of its depth, or with the notch somewhat
 shallower and continued as a groove to the base of the labrum;
 North American species with small dorsal hair pencils
 (*Apatelodes*) **EUPTEROTIDÆ**
 Labrum less deeply notched, the notch not continued by a groove; no
 dorsal hair pencils **LASIOCAMPIDÆ** p. 486
74. Eighth segment of abdomen with a mid-dorsal horn, plate, or tuber-
 cle 75
 Eighth segment of abdomen not armed in mid-dorsal line. 79
75. Body with numerous branching spines or enlarged tubercles. 76
 Body with at most two pairs of small spines on thorax 78
76. Head angulated or spined dorsally, or abdomen with several mid-
 dorsal spines; hooks of prolegs usually triordinal . **NYMPHALIDÆ** p. 511
 Head evenly rounded; hooks biordinal 77
77. A mid-dorsal spine on ninth segment of abdomen; spines of body seg-
 ments strongly unequal, and armed with short nodules or spiracles
CITHERONIIDÆ
 No mid-dorsal spine on ninth segment, or body spines subequal and
 armed densely with long poison-spinules **SATURNIIDÆ** p. 491
78. Segments with six or eight annulets, prolegs normal in position
SPHINGIDÆ p. 481
 Segments with two or three obscure annulets; prolegs unusually widely
 separated **BOMBYCIDÆ** p. 488
79. Head high, triangular (*Lapara*) **SPHINGIDÆ** p. 481
 Head not triangular 80
80. An inconspicuous mid-dorsal spine on ninth abdominal segment
 (*Anisota*) **CITHERONIIDÆ**
 No mid-dorsal spines 81
81. Hooks in an ellipse, at most narrowly interrupted . . . **HESPERIIDÆ** p. 497

- Hooks in one band, occasionally interrupted, rarely in two widely separated bands 82
82. Band of hooks reduced or interrupted at middle. 83
- Principal band of hooks continuous 84
83. Head half diameter of body; secondary hair relatively prominent
- RIODINIDÆ**
- Head rarely more than a third as wide as body; secondary hair less prominent. **LYCÆNIDÆ** p. 513
84. A forked, eversible dorsal gland or osmeterium just behind head
- PAPILIONIDÆ** p. 500
- No osmeterium 85
85. Body with branching spines, high hairy tubercles, fleshy filaments, when these are reduced there are large spines or tubercles on the head 89
- Body without spines, warts, or filaments; anal plate rounded; head rounded 86
86. Prolegs with only a single row of hooks, forming a curved band . . . 87
- Prolegs with reduced hooks on outer side in addition to a well-developed band; head small; setæ never on prominent warts **LIBYTHEIDÆ**
87. Head larger than prothorax **NYMPHALIDÆ** p. 511
- Head smaller than prothorax 88
88. Setæ usually borne on prominent warts (**ASCIIDINÆ**)
- Setæ not borne on prominent warts **PIERIDÆ** p. 506
89. Mesothorax and sometimes several other segments bearing fleshy filaments; secondary setæ short and confined to prolegs . . . **DANAIDÆ** p. 508
- Body without fleshy filaments 90
90. Body spines slender, at least 12 times as long as wide, those on abdomen as long as width of mesothorax; each abdominal segment with three lateral spines but without median dorsal spines . . . **EUEIDIDÆ**
- Body spines, when present, not so slender, those on abdomen shorter than width of mesothorax; median spines usually present
- NYMPHALIDÆ** p. 511

KEY TO SUBORDERS

1. Venation of fore and hind wings similar; wings united or coupled by a jugum or a fibula **JUGATÆ**
2. Venation of the fore and hind wings dissimilar; wings united or coupled by a frenulum or a humeral area **FRENATÆ** p. 440

I. Suborder **JUGATÆ** Comstock 1892

(**HOMONEURA** Tillyard 1918)

KEY TO SUPERFAMILIES

1. Tiny or small moths; wing expanse 12 mm. or less; wings coupled by a jugal lobe or fibula; maxillary palpi abortive or absent
- MICROPTERYGOIDEA** p. 439

2. Small to large moths; wing expanse 15 mm. or over; wings coupled by jugum; tibial spurs present; proboscis short or abortive; maxillary palpi well developed **HEPIALOIDEA**

(1) Superfamily **MICROPTERYGOIDEA** Dyar 1902

KEY TO IMPORTANT FAMILIES

1. Mandibles present; functional and dentate; lacinia and galea present; galea not elongated; middle tibæ without spurs **MICROPTERYGIDÆ**
Mandibles absent or greatly reduced and not dentate; lacinia absent; galea elongated; middle tibæ with one or two spurs 2
2. Mandibles mere functionless lobes; maxillæ with long five-segmented palpi; proboscis short. **ERIOCRANIIDÆ**
Mandibles absent; maxillæ with vestigial three-segmented palpi; proboscis well developed **MNESARCHÆIDÆ**

Family MICROPTERYGIDÆ Comstock 1893 (Mi-crop'ter-ig'i-dæ, from the Greek *μικρός*, little, + *πτερυξ*, *πτέρυγος*, wing; referring to the very small wings of these tiny moths). German, Urmotten. Primitive Moths.

Tiny somber diurnal moths with a wing expanse of only 8–12 mm. Head small. Antennæ much shorter than the wings. Mouth parts of the primitive type with short or atrophied proboscis and large mandibles, the latter to crush the pollen and fungus upon which they feed. Labial palpi well developed and three-segmented. Hind tibæ with four spurs. Wings dull or metallic; scales without cross striæ and pigmentation; each pair with 12 veins; M forking at or beyond middle; without closed median cell; jugal lobe or fibula present; held roof-like and similar to those of archaic TRICHOPTERA. In the female the oviduct and rectum unite into a common duct. Lateral glandular openings on abdominal segment V in both sexes of many species. Male genitalia exserted.

Larvæ elongated or cylindrical, somewhat resembling those of the slug moths and certain of the MECOPTERA; body bearing large ovate paired scales. Head retractile; antennæ large, three-segmented; a pair of five-faceted compound eyes; prolegs, eight segmented pairs with claw-like true legs, sometimes abbreviated in more mature forms. They live chiefly on liverworts and are rarely collected. Pupation occurs in tough oval cocoons attached to some object. Pupæ free with normally placed and functional mandibles.

The family is a very small one but widely represented in the Palæarctic region by the genus *Micropteryx* Hübner (10 species); in New Zealand by *Sabatinka* Walker and *Micropardalis* Meyrick (17 species); and in North America by two genera, *Acanthopteroctetes* Braun and *Epimartyria* Walsingham.

(2) Superfamily **HEPIALOIDEA** Mosher 1916

Family HEPIALIDÆ Stephens 1829 (He'pi-al'i-dæ, from the Greek *ήπιόλος*, a moth or a ghost moth). Hepialid Moths, Ghost Moths, Swift Moths.

Dull to brilliantly colored, medium-sized, robust, hairy moths which are both diurnal and nocturnal in habits. Head small, hairy. Antennæ short,

moniliform, and often pectinate in the males. Ocelli absent or rudimentary; concealed beneath the hair. Mouth parts vestigial; the adults apparently feed little or not at all. Proboscis represented only by the basal segment. Mandibles and maxillæ vestigial. Labial palpi small and hairy. Thorax well developed, hairy. Legs weak and lacking spurs; the hind pair in the males may have a large tuft of hair. Wings long and rather narrow; hind pair much smaller; anal veins reduced; jugum slender; frenulum absent; venation primitive, Cu_2 only partly developed in the fore pair. Abdomen large; female genital organs specialized and complicated.

The females of certain known species scatter or spray the somewhat disk-like eggs over the host plants in flight. The caterpillars are cylindrical, often quite large; somewhat wrinkled; yellowish, whitish, or dusky; with hairs arising from small dark body tubercles; six ocellanæ in two rows of three on each side of the polished elongated or nearly globular head; three pairs of true legs and five pairs of prolegs. They are apparently all plant borers and feed in the roots, trunks, limbs, twigs, and stems of annual and perennial grasses, plants, shrubs, and trees. Some of them are of considerable economic importance. The pupæ are cylindrical; with dorsal and ventral spines; abdominal segments III to VII free in the male and III to VI free in the female; spiracles on abdominal segment I invisible. Pupation occurs within the silk-lined burrows.

This family constitutes a primitive group of moths placed close to the MICROPTERYGIDÆ. It embraces 23 genera and 200 species which are widely distributed but attain their greatest development in the Southern Hemisphere in Australasia and South America and especially in the former region where occur many remarkable species. The largest species are the Australian *Charagia nobilis* Turner, *C. mirabilis* Rothschild, and the bent wing moth, *Leto stacyi* (Scott). The latter Tillyard says is the finest known species in the family. These have a wing expanse of 175 mm. and are arrayed in brilliant colors. The larvæ of *Charagia* burrow into the twigs of native shrubs and trees and fruit trees while the larvæ of *Leto* tunnel into the roots of large eucalyptus trees. The larvæ of the latter are up to 153 mm. long, and the burrows are plugged with a silken wad which the pupa pushes out before emergence.

Larvæ of the European *Hepialus humuli* (Linn.) and *lupulinus* (Linn.) infest the roots of a large number of annual and perennial plants. *H. gracilis* Grote of North America and *H. hecata* (Linn.) of Europe attack the roots of ferns. Members of the genera *Pielus* Walker and *Trictena* Meyrick infest the roots of trees. The caterpillars of *Oncopera* Walker are serious pests feeding on the roots of grasses in pastures, greens, and lawns in Australia.

II. Suborder FRENATÆ Comstock 1892

(HETERONEURA Tillyard 1918)

KEY TO SUPERFAMILIES

(Adapted from Tillyard, Comstock, Brues and Melander, and others.)

1. Vein M and two main branches complete and conspicuously formed within the cell; Cu_2 present in both pairs of wings; areole present in

- fore wing; proboscis absent. Larvæ wood borers. (Carpenter or Goat Moths.) **COSSOIDEA** p. 443
- Vein M and two main branches incomplete or, if complete as indicated above, then the areole is absent. 2
2. Vein M present as a simple vein within the basal cell or rarely branched in one or both pairs of wings 3
- Vein M and its branches greatly reduced or absent in the basal cell 4
3. Fore wings with M_{3+4} well developed within the cell; M_{1+2} usually absent; hind wings with M_{3+4} only present and far removed from R_s and near Cu_1 ; hind wings with Cu_2 vestigial. Maxillary palpi present; labial palpi short; proboscis present or absent; antennæ clavate. Day-flying moths of Australia and South America. Larvæ burrow in stems or roots of grasses. **CASTNIOIDEA** p. 446
- Fore wings with single stem of M extending through and branching beyond the cell; both wings with Cu_2 well developed (rarely wanting in either); hind wings with SC + R, remote from R_s beyond the cell; proboscis and palpi atrophied; posterior tibial spurs much reduced; middle spurs often absent. The larvæ live freely, in cases or as wood borers, and the adults are diurnal and nocturnal. (Bagworms, Case Moths, Burnet Moths, Foresters, Cup Moths.) (See couplet 6.) **ZYGÆNOIDEA** p. 469
4. Wings with aculeæ, or minute needle-like spicules, over the general surface 5
- Wings with aculeæ absent or confined to only small areas. 6
5. Venation fairly complete; antennæ without eye cap; ovipositor piercing. Larvæ, case bearers or borers. Adults, small to minute; some with very long antennæ. (Case Bearers, Yucca Moths, Leaf Miners.) **INCURVARIOIDEA** p. 451
- Venation much reduced; cell very small or absent; antennæ with large eye cap; ovipositor absent; labial palpi short; maxillary palpi long; proboscis vestigial. Larvæ miners and rarely gall makers. Adults minute **NEPTICULOIDEA** p. 450
6. Wings large; venation primitive; Sc and R of hind wings usually uniting along cell. (See couplet 3.) **ZYGÆNOIDEA** p. 469
- Wings large or small; venation well developed, soft scaled with or without long fringes, often linear or lanceolate in small species; Sc and R of hind wings rarely or never fusing beyond cell and rarely fusing at all; proboscis may be scaled at base 7
7. Wings with soft scales and small anal regions 8
- Wings with firm fine scales and ample anal regions; fore wings with areole; Cu_2 generally present in hind wings; maxillary palpi reduced; labial palpi moderately well developed and porrect; proboscis usually present; legs long and slender. Larvæ mostly phytophagous and saprophagous. Large group of small to medium-sized moths. (Pyralid Moths.) **PYRALIDOIDEA** p. 463
8. Fore wings with first A rarely lost unless wing is very narrow . . . 9
- Fore wings with first A almost always rudimentary or lost . . . 14
- Fore wings usually long and narrow, with first A strong and tubular, without areole, and R_3 and R_4 nearly always coincident; hind wings

- usually short, with Sc well separated from cell throughout; proboscis well developed and often very long; body fusiform, stout. Larvæ often with anal horn, phytophagous, and living freely on plants. Adults diurnal, crepuscular, and nocturnal; strong fliers. (Sphinx Moths, Hawkmoths, Hummingbird Moths.). . . . **SPHINGOIDEA** p. 481
9. Hind wings with Sc and R typically approximate at base. . . . 10
Hind wings with Sc and R widely separated; fore wings often with one or two veins absent; maxillary palpi vestigial or absent; labial palpi long and upcurved or short and drooping. Larvæ phytophagous and with variable habits. Moths mostly small **ELACHISTOIDEA** p. 458
10. Head usually smooth 11
Head usually rough 12
11. Radial branches all usually present and extending to the costa; ocelli small or absent; antennæ with or without a basal fringe of strong bristles or *pecten*, without eye cap; proboscis moderately long; maxillary palpi reduced or absent; labial palpi long and porrect; hind tibiæ usually rough haired; hind wings usually broader than the fore pair. Larvæ small or minute, phytophagous, often gregarious; many spin leaves and shoots **GELECHIOIDEA** p. 456
Radial branches not all present; R₅, when present, extending to costal margin; hind tibiæ usually smooth. Larvæ, leaf eaters and wood borers. Adults small to minute. (Ermine Moths, Clear Wings, Hornet Moths.) **YPONOMEUTOIDEA** p. 451
12. Hind wings with R and M₁ separate; palpi often folded 13
Hind wings with R and M₁ usually approximate or stalked; palpi triangular or porrect; maxillary palpi vestigial or absent; labial palpi with second segment somewhat rough-scaled and apical segment short and obtuse; hind wings as wide as or wider than fore wings. Larvæ often concealed in curled and spun leaves, stems, roots, flowers, fruits, and seed pods. Adults small to medium-sized moths. (Leaf Rollers, Bell Moths.). **TORTRICOIDEA** p. 459
13. Wings entire and usually fringed; legs moderately long; proboscis scaled when present; maxillary palpi folded; labial palpi either bristled or with the first segment enlarged. Larvæ phytophagous and coprophagous. Moths small and variable. (Tineid Moths, Clothes Moths.) **TINEOIDEA** p. 446
Wings usually deeply cleft; legs long and slender with long tibial spurs; Cu₂ always persisting distally in fore wings and absent in hind wings; M₂ arising separately in all wings. Larvæ phytophagous and burrowing into flower and seed heads and shoots. Moths small and delicate. (Plume Moths.) **PTEROPHOROIDEA** p. 462
14. Abdomen with chitinated tympanum or hood at ventral base . . 15
Abdomen without tympanum or hood 17
15. Abdominal tympanum or hood small; proboscis present; maxillary palpi absent; fore wings without areole; hind wings without Cu₂; frenulum present or absent. Larvæ phytophagous, often ornamented with body processes. Adults small to large, slender, often brightly colored tropical species; some have fore wings rolled at rest, others have tails; diurnal **URANIOIDEA** p. 480

- Abdominal tympanum or hood well developed and large . . . 16
16. Hind wings with $Sc + R$, approximate or partly joined to R_s beyond the cell; areole usually present in fore wings; fore wings hooked at tips in some species; proboscis present or absent; labial palpi slender and often minute. Ocelli well developed or vestigial. Larvæ with anal prolegs reduced or absent. Adults medium-sized, mostly diurnal. (Hooktip Moths.) . . . **DREPANOIDEA** p. 480
- Hind wings with $Sc + R_1$ remote from R_s beyond the cell; Cu_3 absent from all wings; proboscis only rarely absent; maxillary palpi vestigial. Larvæ are variously called loopers, measuring worms, cankerworms; long and slender, with reduced number of abdominal legs; often assume rigid poses; phytophagous and often plant defoliators. Moths variable in size; somewhat delicate; females in some species with vestigial wings; mostly crepuscular and nocturnal; wings folded back to back above or horizontally over the body at rest. (Geometers, Carpets, Waves, Pugs.) . . . **GEOMETROIDEA** p. 483
17. Tympanum or hood developed on sclerites in the metaepimeron; proboscis present or absent; ocelli present; maxillary palpi minute or absent; Cu_2 absent from all wings. Larvæ variable, phytophagous, and some species very destructive to plant life. Adults medium-sized to large. (Noctuids, Harness Moths, Tiger Moths, Prominents, Tussock Moths.) . . . **NOCTUOIDEA** p. 471
- Tympanum or hood absent . . . 18
18. Hind wings with $Sc + R$ connected with cell by two or more stout humeral veins; frenulum absent; Cu_2 absent from all wings; proboscis rudimentary or absent; palpi greatly reduced; antennæ short and conspicuously bipectinate; tibial spurs short or absent. Larvæ large, highly specialized, with vestigial secondary hairs and *scoli*, or spined tubercles. Moths large, soft-scaled, and hairy; the wings often having transparent eyespots; many beautifully colored. (Wild Silkworms, Emperor Moths, Day Moths.) . . . **SATURNIOIDEA** p. 490
- Hind wings with $Sc + R$ connected with cell by one cross vein or bar; Cu_2 absent from all wings; frenulum rudimentary or absent; proboscis reduced or absent; maxillary palpi absent. Larvæ apparently smooth or warty and with fine secondary hairs often mixed with scales; some with tufts of hair. Adults medium-sized to large moths. (Chinese Silkworm, Silk Moths.) . . . **BOMBYCOIDEA** p. 486

(3) Superfamily COSSOIDEA Tillyard 1926

KEY TO IMPORTANT FAMILIES

1. Fore wings with A_1 and A_2 free, or A_1 absent . . . 2
Fore wings with A_1 and A_2 connected by a cross vein near margin. Larvæ wood borers. Nearctic . . . **HYPOPTIDÆ**
2. Frenulum present . . . 3
Frenulum absent. Indo-Australasian . . . **RATARDIDÆ**
3. Hind wings with R_s and M_1 widely separate; labial palpi minute. Larvæ wood borers. Adults medium-sized moths. Widely distributed. (Leopard Moths.) . . . **ZEUZERIDÆ** p. 445

Hind wings with R_s and M stalked beyond end of cell; fore wings often large, areole present, Cu_2 well developed; maxillary palpi, proboscis, and ocelli absent. Larvæ wood borers, often large. Adults large with narrow wings. Widely distributed. (Carpenter Moths, Wood Moths.)

COSSIDÆ

Family COSSIDÆ (Leach 1815), Walker 1855 (Cos'si-dæ, from the Latin *cossus*, a kind of larva under bark of trees). German, Holzbohrer. French, Cossioidea. Wood Moths, Goat Moths, Carpenter Moths, Cossids.

Medium-sized to large, 35–180 mm. wing expanse, hairy and scaly nocturnal moths which sometimes have a decidedly greasy appearance. Colors cryptic, gray or brownish with dusky spots, hind wings may be bright; males usually smaller than females and brighter in color. Proboscis and maxillary palpi absent; labial palpi short or vestigial, upturned. Antennæ smooth, pectinate, or plumose. Tibial spurs variable. Wings with primitive type of venation; folded flat over back in repose; clothed with closely appressed scales and with long hairs especially at the bases; fore wings with areole; frenulum present, hind wings with R_s and M_2 close together or stalked beyond apex of discal cell. Abdomen robust or long and slender and pointed posteriorly; hairy. Eggs globular, sculptured, laid singly or in masses on the bark or in the old burrows. Larvæ with only primary setæ; somewhat flattened; head and prothoracic shield heavily chitinized; mandibles large and strong; five pairs of prolegs, crochets in two series in circlets; color varying from yellowish-white to pink with dusky dorsal markings. Pupæ free, the dorsum of each abdominal segment furnished with one or two raised serrated or spined bands; enclosed in a cocoon of silk and frass within the burrows which are extended to the surface and plugged with frass by the caterpillars prior to pupation.

The family is a small one more or less restricted to the deciduous forests of the temperate regions of the world.

The most noted species is the common goat moth, *Cossus cossus* (Linn.) (= *ligniperda* Fab.) of Europe, the large larvæ of which bore into the trunks and limbs of broad-leaved deciduous trees and large shrubs. This insect was included in such early historical entomological works as Aldrovandus 1602, Mouflet 1634, Goedart 1659, Merian 1730, Albin 1728, Réaumur 1734, Roesel 1746, and DeGeer 1752. It has been made famous throughout all time by marvellous early anatomical researches on the larvæ by Pierre Lyonet in 1760.¹ The adults are dull brownish-gray with a wing expanse of 60–95 mm. The caterpillars are dull pale yellowish-red with dark brownish-red dorsum and may attain a length of 75 mm. They make large tunnels in the trunks and large limbs of all the common deciduous trees: alder, ash, beech, birch, elm, fruit trees, grape vines, linden, maple, mulberry, oak, poplar, walnut, willow, and other related forms.

The carpenter or goat moth, *Prionoxystus robinix* (Peck), one of the first

¹ *Traité Anatomique de la Chenille, qui ronge le Bois de Saule*. La Haye, pp. 22 + 587 + 3, 18 pls. 1760.

insects described by an American entomologist,¹ is a similar large and destructive species. The adults have a wing expanse of 50–85 mm., and are mottled gray. The males are only about half as large as the females. The fore wings of the male are dark gray, and the hind wings are ochre-yellow or orange-red lined with black. The adults appear in June and July, and the females deposit their eggs in the cracks or crevices of the bark or in or near wounds or the openings of old burrows. The eggs are oval or elongated, slightly larger than a pinhead, finely reticulated, dirty white or greenish, and sticky. As many as 200–300 are laid by a single female. The larvæ immediately enter into the solid wood of the tree where they make large galleries which frequently cause the death of the host. When mature they are white or pinkish with dark head and shield and brown spots at the bases of the scattering body hairs. They attain a length of 65 mm. Three years are required to complete a life cycle. The Australian *Xyleutes boisduvali* Herrich-Schaffer is the heaviest bodied moth in the world, according to Tillyard.

The caterpillars attack nearly all of the common broad-leaved deciduous wild, ornamental, and fruit trees. The distribution embraces much of North America.

Family ZEUZERIDÆ (Boisduval 1829), Butler 1886 (Zeu-zer'i-dæ, origin uncertain). Leopard Moths.

A small family of hairy and scaly moths separated from the COSSIDÆ in characters of wing venation including the wide separation of R_s and M_1 of the hind wings. The labial palpi are very short. In the larvæ, setæ II are on a common dorsal plate on abdominal segment IX, and the adfrontal plates do not reach the vertex. Their general habits are similar to those of the carpenter worms. The larvæ of a number of species are very destructive borers in the heartwood of trees, shrubs, and woody plants.

The most important genus is *Zeuzera*² Latr. with 42 species. Of these the leopard moth, *Z. pyrina* (Linn.) (= *æsculi* Linn.), is the most important. The adults are semitransparent white with many conspicuous circular and elongated black spots on the wings; expanse of females 50–75 mm.; the males considerably smaller. The caterpillars are pale yellow with a few slightly raised, shining, black papillæ. They attain a length of 75 mm. The young larvæ first bore into the twigs and later move to the branches and trunks of a wide variety of deciduous trees such as ash, apple, beech, birch, cherry, currant, dogwood, elm, hazel, hickory, horse chestnut, maple, oak, olive, pear, plum, walnut, and their relatives. Two years are required to complete a life cycle. This is a European species which was introduced into New York and there discovered in 1882 and has since spread to neighboring Atlantic coast states. The coffee borer, *Z. coffeæ* Nientner, is a pest of coffee in Indo-Malaysia and eastern Asia. The acacia borer, *Z. eucalypti* (Boisduval), attacks acacia and fruit trees in Australia.

¹ Described as *Cossus robinix* by W. D. Peck in 1818 from locust in Massachusetts.

² The genus *Zeuzera* was originally misspelled *Zenzera*.

The genus *Xyleutes* Hübner is well represented in Australia and Malaysia. In it is the largest member of the family and one of the largest moths, *X. boisduwali* Rothschild, with an expanse of 250 mm., larvæ 180 mm., and pupæ 125 mm. long. It attacks eucalyptus in Queensland.

(4) Superfamily CASTNIOIDEA Handlirsch 1925

KEY TO FAMILIES

1. All wings with first A present, discal cell small and closed; Sc and R₁ of hind wings sharply diverging from the base of the cell; proboscis developed; antennæ clubbed. Often brightly colored, day-flying moths resembling certain butterflies. Neotropical, Australian, and Oriental CASTNIIDÆ
2. All wings with first A reduced, discal cell open; proboscis vestigial. Oriental TASCINIDÆ

(5) Superfamily TINEOIDEA Dyar 1902

KEY TO IMPORTANT FAMILIES

1. Basal segment of antennæ enlarged and concave beneath, forming an eye cap 2
 Basal segment of antennæ not enlarged to form an eye cap, sometimes provided with tufts of scales or a pecten of bristles; venation reduced; wings linear-lanceolate with sharply pointed apices, fore wings with veins at apex of discal cell radially diverging; hind wings without discal cell, the principal vein axial 3
2. Labial palpi minute, drooping, or absent; fore wings typically with closed anal cell, or the vertex rough. Adults minute to small varicolored moths. Cosmopolitan LYONETHIDÆ p. 448
 Labial palpi moderate in size, upcurved; anal cell absent; vertex smooth; eye cap small, pecten absent; discal cell extending almost to tip of wing, its posterior edge straight, branches R, M, and Cu short; hind tibiae with row of large bristles. Minute whitish species widely distributed PHYLOCNISTIDÆ
3. Vertex and upper face tufted with dense bristly hairs; mouth parts vestigial. Larvæ gall makers. South American . . . RIDIASCHINIDÆ
 The face, at least, smooth and with short scales, even though the vertex be rough-crowned 4
4. Mouth parts well developed; labial palpi scaled or short haired, segment III usually long and pointed or very short in roughly scaled species 5
 Mouth parts undeveloped; fore and hind wings each with single anal vein and short fringe. Larvæ gall makers. South American . . . CECIDOSIDÆ
5. Fore wings with R₃ free, arising from the accessory cell 6
 Fore wings with hyaline aculeate fovea in accessory cell distorting the venation; R₃, 4, 5 seriatly stalked. Widespread. SETOMORPHIDÆ
6. Labial palpi bristled 7
 Labial palpi scaled or loosely haired 8
7. Vertex with high, rough, bristling vestiture; wing membrane not acu-

leate (without minute needle-like spicules). Larvæ feed on living plants and dried vegetable and animal matter; some are serious pests.

Adults minute to small often tawny moths. Cosmopolitan . . . **TINEIDÆ** p. 449

Vertex with short flattened hairs **AMYDRIIDÆ**

8. Fore wings with all veins present and R_2 extending to outer margin;

hind wings narrow; vertex with small, loose tuft of hairs and scales

only **PLUTELLIDÆ** p. 450

Fore wings with vein R extending only to costa or absent . . . **GENOPHILIDÆ**

Family COLEOPHORIDÆ (Hübner 1816), Stainton 1854 (Col'e-o-phor'i-dæ, from the Greek *κολέος*, sheath, + *φορός*, bearer, one that bears; in reference to the case or sheath in which the larvæ live). Case Bearers.

Minute to small moths, wing expanse 7–16 mm., usually pale in color. Head smooth; body with closely appressed scales. Antennæ long, rough-scaled, porrect in repose. Labial palpi moderate, ascending; maxillary palpi absent. Wings slender, often pointed apically with rear marginal fringes, especially the hind pair; fore wings without more than 11 veins; frenulum long. Larvæ small, pale, with minute setæ; thoracic legs present; prolegs present or absent, crochets uniordinal; spiracles circular, minute. The caterpillars live first as leaf miners and then form and inhabit cases made from leaf tissues. These cases are of various shapes and colors and are carried about by the larvæ which feed inside the leaves, flowers, fruits, and seeds by partly withdrawing from the cases to eat holes through the epidermis. In some instances the larva is able to excavate large blotches on the leaves. Hibernating larvæ may remain in the cases attached to the bark of the host plants. Pupation occurs within the case, which is firmly attached at the opening which is thus sealed.

The family is a relatively small one consisting of less than 1,000 species widely distributed but most abundant in southern Europe and the United States. The members feed upon many kinds of trees and shrubs and occur in forested areas. The most important genus is *Coleophora* Hübner which may have up to 500 species and which includes all of the 90 North American members of the family. The two most important American species are the cigar case bearer, *C. fletcherella* Fernald, which feeds on apple, cherry, hawthorn, and pear; and the pistol case bearer, *C. malivorella* Riley, which is a pest of apple. The common names are derived from the shapes of the dark larval cases. Both occur in northeastern United States and throughout much of southern Canada.

Family GRACILARIIDÆ Rebel 1901 (Grac'i-lar-i'i-dæ, from the Latin *gracilis*, slender; referring to the slender bodies and wings). Leaf Miners, Blotch Miners, Skin Miners.

Minute to small, slender, gray, brown, tan, silvery, golden, coppery, and other metallic-colored moths which often rest with the fore part of the body raised. Head smooth or somewhat rough. Antennæ as long as or longer than the fore wings; two whorls of scales to each segment. Eye cap rarely absent.

Ocelli generally present in family as now restricted. Proboscis well developed. Palpi normal or short; labial palpi upturned with segment III at right angles to II and blunt or fusiform; maxillary palpi three-segmented, porrect, reduced, or absent. Wings without aculeæ or microtrichia; fore wings narrow and sometimes drawn out into a long point and without stigma; hind wings narrower.

The larvæ are of two types, the young and the older forms. The young have the head flat, ocellanæ very small and variable in number, being reduced even to just a single pair; rarely apodous; prolegs vestigial or absent when thoracic legs are present, always absent on abdominal segment VI. Crochets uni- or biordinal. Mature caterpillars are cylindrical, with normal head, minute body setæ, and prolegs well developed on segments III to V and last.

The young caterpillars are usually miners of leaves, bark, or fruits, and puncture the plant cells with their flat mandibles to suck up the sap. Later stages feed normally upon the green tissues within the mines, or they may fold, web, and skeletonize or devour the leaves. Certain ones mine the stems and fruit, and the members of the oriental genus *Epicephala* Meyrick feed on seeds. Pupation occurs in thin cocoons within the mines or rarely in rolled leaves or elsewhere outside the mines. The pupæ protrude from the cocoons upon emergence of the adults.

The family is widely distributed throughout the world. The most primitive genus is *Gracilaria* Haworth with about 120 described species. One of the best known species is the European lilac leaf miner, *G. syringella* (Fab.), which has been introduced into parts of North America. The azalea leaf miner, *G. azaleæ* Busck, introduced from Japan into North America, is a pest in greenhouses. *G. coffeifoliella* Motschulsky attacks coffee in western Africa, and *G. theivora* Walsingham infests tea in Malay. The genus *Lithocolletis* Hübner is the largest and most important in the family and includes more than 200 species, many of which are quite destructive to forest, ornamental, and cultivated shrubs and trees particularly of the north temperate regions. It is believed to have originated recently in North America. Needham, Frost, and Tothill (1928) list 94 leaf-mining species in this country, and Forbes (1923) describes 73 from New York and neighboring states. The larvæ mine mostly the foliage of broad-leaved deciduous trees.

Members of the genus *Marmara* Clemens are important because the minute flat larvæ of certain species, notably *M. pomonella* Busck of North America, mine the outer epidermis of fruits while other species mine both fruits and the stems, shoots, and branches of shrubs and trees. Pupation occurs in a thin cocoon outside the mine which in the case of *M. arbutiella* Busck is decorated by small white translucent globules excreted from the anus.

Family LYONETHIDÆ Stainton 1854 (Ly'o-net-i'i-dæ, named for the Dutch entomologist and naturalist, P. Lyonet, who published a remarkable work on the anatomy of the European goat moth in 1760). Ribbed-case Bearers.

A small family of widely distributed minute moths scarcely larger than those in the family NEPTICULIDÆ. The adults are often brilliantly colored.

Head crowned with rough scales or hairs; face smooth. Antennæ dilated basally into an eye cap; may be grooved ventrally. Ocelli absent. Proboscis poorly developed or obsolete. Maxillary palpi developed or usually vestigial or absent. Labial palpi short and scaled. Hind tibiæ with long dorsal bristle. Fore wings lanceolate and often with the tips drawn out into a slender curved prolongation. Hind wings linear, with long fringes. Eggs flattened. Larvæ flat or nearly cylindrical; with true legs and five pairs of prolegs; crochets in single series. Mouth parts reduced. Six ocelli in two groups.

The caterpillars are mostly leaf miners. Those of *Bucculatrix* are first miners and later skeletonizers. Pupation occurs in cocoons. In *Bucculatrix* the cocoons are ribbed and surrounded by a palisade of erect silken filaments. These moths frequent forested and shrubby areas and orchards. The most important genera are the almost cosmopolitan *Lyonetia* Hübner, *Bedellia* Stainton, the widely distributed *Bucculatrix* Zeller, and the Australian *Phyllobrostitis* Staudinger and *Opogona* Zeller. The ribbed cocoon maker, *Bucculatrix pomifoliella* Chambers, which mines the leaves of apple is a common species in eastern North America. The European *Bedellia somnulentella* (Zeller) mines the leaves of *Ipomœa* and has been introduced into eastern North America and Australia.

Family TINEIDÆ¹ (Stephens 1829), Wocke 1891 (Ti-ne'i-dæ, from the Latin *tinea*, a worm, moth). German, Echte Motten. French, Teignes. Tineid Moths, Clothes Moths.

Small, somber-tan, brown, grayish and dull or iridescent diurnal and nocturnal moths. Head roughened by erect hairs and scales. Antennæ rarely as long as the fore wings; usually with a whorl of bristles at the bases of the segments. Eyes often small; naked. Proboscis usually present. Maxillary palpi long, five-segmented; folded or straight, short or absent. Labial palpi small to medium-sized; porrect or upturned; clothed with setæ and scales. Hind tibiæ may be spurred. Wings narrow; veins free. Larvæ mostly pale; prothoracic prespiracular setæ close together; prolegs with crochets uniordinal and arranged in an ellipse or interrupted by a small break on the inner side, anal pair with a short incomplete band. Pupæ may have two posterior spines; enclosed in a silken cocoon or larval case.

The caterpillars are largely saprophagous and feed upon dried animal and vegetable matter and fungi.

The family, as now defined, while relatively small is widely distributed. The most important species are the clothes moths which are of Old World origin and are now cosmopolitan in distribution. The three common important destructive species are the case-making clothes moth, *Tinea pellionella* (Linn.), grayish-yellow with dusky spots on the middle of the fore wings, 5-8 mm. long, and an expanse of 10-15 mm. The dull white larvæ live in portable parchment-like cases constructed of wool, hair, and refuse bound together with silken

¹ As originally conceived, this family contained a very great number of the small moths generally known as MICROLEPIDOPTERA, as evidenced by Stainton's *Natural History of the TINEINA*, 13 vols., 1855-1893. At the present time the family is comparatively restricted.

threads and feed on wool, hair, dried insects, skins, feathers, and other animal products. *Tinea fuscipunctella* Haworth, a European scavenger, is reported as an introduced clothes moth in Australia and New Zealand (Tillyard, 1925). The webbing clothes moth, *Tineola biselliella* Hummel, pale ochreous throughout, 4–8 mm. long, has an expanse of 9–14 mm. The larvæ are not enclosed in cases but web together the particles on which they feed. The food habits are similar to those of the preceding species. This is the commonest and most widely distributed member of the family. The tapestry moth, *Trichophaga tapetiella* (Linn.), is creamy white or grayish with the basal third of the fore wings black and is somewhat larger than the preceding species, having a wing expanse of 14–16 mm. The larvæ form silk-lined galleries through masses of wool or hair upholstery, carpets, blankets, feathers, and similar food materials. It is not as common as the other species.

The larvæ of *Myrmecozela ochraceella* Tengström live in cases and are myrmecophilous in Europe.

Family PLUTELLIDÆ (Guenée 1845), Stainton 1854 (Plu-tell'i-dæ, from the Greek πλούτος, wealth; application uncertain). Plutellid Moths.

Small, cryptic-colored, narrow moths; head smooth or somewhat rough; antennæ directed forwards with pecten and slightly roughly scaled. Ocelli minute. Maxillary palpi short, filiform, porrect; labial palpi moderate, directed upwards, apical segment long and acute. Hind tibiæ smooth. Wings narrow; fore wings sometimes sickle-shaped; hind wings elongate-ovate; M_1 and M_2 stalked. Larvæ small, cylindrical, often green; crochets of prolegs in single circle; spin fine webs. Cocoons open and lace-like. A small family of phytophagous species. The genus *Cerostonia* Latreille is Holarctic and Neotropical. *Plutella* Schrank is represented by the nearly cosmopolitan diamond-backed moth, *P. maculipennis* Curtis (= *cruciferarum* Zeller), gray or brownish with white marks on the costal margins of the fore wings which when folded form a diamond; expanse 18–20 mm. The small green caterpillars are first miners and later surface feeders on cruciferous plants.

(6) Superfamily NEPTICULOIDEA Forbes 1923

Family NEPTICULIDÆ (Tutt 1899), Spuler 1910 (Nep'ti-cul'i-dæ, from the Latin *nepticula*, a little granddaughter; referring perhaps to the small size of these moths). Nepticulid Moths, Serpentine Miners.

A family of minute, varicolored moths from 3–10 mm. long and with a wing expanse of 3.25–10 mm. *Nepticula microthierella* Stainton, which mines the leaves of white birch and hazel in Europe, has a wing expanse of only 3 mm. and according to Imms is probably the smallest species in the order. They are retiring in habits and have an erratic flight but sometimes appear simultaneously in great numbers for only a short time. Head rough and tufted. Antennæ not so long as the wings; basal segment enlarged to form an eye cap. Wings wide or lanceolate and pointed anteriorly; membrane spiny; venation much

reduced, veins branched; cells may be absent; frenulum rudimentary or consisting of one strong or several weak spines. Larvæ minute, 2.5–10.0 mm. long, living mostly as miners in leaves and sometimes in fruit and bark. The mines are linear or serpentine. Certain species of *Ectademia* are gall makers. Pupation usually occurs in thick cocoons in litter or loose soil.

This comparatively small family occurs most abundantly in forested and brush-covered areas and in orchards and ornamental plantings. The most important genera include the cosmopolitan *Nepticula* Heyden; the European *Opotege* Zeller, *Trifurcula* Zeller, and *Scoliaula* Meyrick; and the American *Ectademia* Busck, *Glaucopis* Braun, and *Obrussa* Braun. The biology of *Nepticula braunella* Jones, on *Prunus ilicifolia*, in California has been published by Jones (1933).

(7) Superfamily INCURVARIOIDEA Forbes 1923

KEY TO FAMILIES

1. Adults, especially the males, with the antennæ as long as or even $2\frac{1}{2}$ times as long as the body; eyes of males often much enlarged. Larvæ first miners then case bearers. Adults minute, dull or brightly colored, often metallic; diurnal. (Fairy Moths.) **ADELIDÆ**
Adults without conspicuously developed antennæ 2
2. Folded part of maxillary palpi half as long as width of head. Larvæ leaf and needle miners. Adults tiny, inconspicuous. (Needle Miners.)
INCURVARIIDÆ
Folded part of maxillary palpi two thirds as long as width of head.
Larvæ seed and stem borers. Adults small and mostly pale-colored moths. (Yucca Moths, Bogus Yucca Moths.) **PRODOXIDÆ**

(8) Superfamily YPONOMEUTOIDEA Mosher 1916

KEY TO IMPORTANT FAMILIES

1. Hind wings with R and M_1 approximate, connate, or stalked . . . 2
Hind wings with R and M_1 well separated at origin, at least half as far apart as at margin 3
2. Fore wings elongate triangular, costa slightly curved near middle where R_5 ends, Sc , R_1 , and R_2 short and ending before middle of wing, M_1 absent, M_2 and M_3 ending in costal margin; maxillary palpi vestigial. Oriental **STREPSIMANIDÆ**
Fore wings blunt and with anterior veins longer, R_5 long-stalked and extending to outer margin, Cu_1 and Cu_2 widely separated, M_3 terminating beyond wing-tips. Quite large moths, often with wing expanse of 3 in.; brightly colored. Larvæ borers and leaf feeders. Neotropical, Australian, Oriental **XYLORICTIDÆ**
3. Ocelli usually very large and conspicuous; fore wings with R_5 terminating beyond wing-tips; maxillary palpi vestigial or absent. Larvæ feed mostly on sedges and grasses. Adults small and often with metallic colors. Cosmopolitan. **GLYPHIPTERYGIDÆ**
Ocelli small or absent 4

4. Wings in large part transparent and usually devoid of scales except on veins and margins; fore wings narrow; hind wings often clear, with Sc concealed in a costal fold and apparently absent, inner margin of fore wings and costal margin of hind wings each with a series of recurved and interlocking coupling spines; tip of abdomen often with a tuft of scales. Larvæ mostly hairless, whitish borers in stems, roots, and crowns of plants. Adults small to medium-sized dark or brightly colored, often with metallic iridescences and many resemble bees and wasps. Cosmopolitan. (Clear-winged Moths.) . . . **ÆGERIIDÆ**
 Wings normally scaled and without extensive transparent areas; hind wings with Sc evident, though sometimes close to or partly fused with R 5
5. Hind wings large, often wider than fringe, with well-developed anal area, rounded apically, trapezoidal, or deeply notched below apex; M_1 and M_2 separate; venation fairly complete; fore wings with R_1 and R_2 separate, R_3 ending beyond apex. Larvæ small, feeding on buds, foliage, and fruit, or miners, some gregarious web spinners or leaf rollers. Adults somber or whitish and brightly varicolored. Widely distributed. (Small Ermine Moths.) **YPONOMEUTIDÆ** p. 456
 Hind wings narrow and pointed or linear and never much wider than fringe; closed or open discal cell present; venation often much reduced 6
6. Fore wings with open discal cell; hind tibiae heavily spined; tarsi with whorls of bristles at apices of segments; hind legs of adults often elevated in repose. Larvæ small or minute miners, leaf-skeletonizers, and general feeders on plants. Adults small, often beautifully colored. Widely distributed. (Sun Moths.) **HELIODINIDÆ** p. 455
 Fore wings with closed discal cell, hind tarsi without whorls of bristles 7
7. Fore wings with R_1 arising beyond middle of cell and about as long as R_2 . Larvæ leaf folders, miners, and exposed feeders. Cosmopolitan
SCYTHRIDIDÆ
 Fore wings with R_1 arising before middle of cell and longer than R_2 ; hind wings with M_1 and M_2 joined or long-stalked; hind tibiae with long hair; palpi small and drooping. Larvæ twig and fruit miners. Adults minute to small moths. Cosmopolitan. (Cypress Moths.)
ARGYRESTHIDÆ

Family ÆGERIIDÆ¹ Stephens 1829 (Ae'ge-ri'i-dæ, from the Latin *Ægeria*, a nymph in Roman legend). German, Glasflügler. Clear-wings, Glassy-wings.

Small, slender, smoothly scaled moths which are black or dark blue and marked with red and yellow and often with metallic iridescences. The wings

¹ The genus *Sesia* Fab. was erected in 1775 to include the clearwing sphinx moths, *Sphinx fusciformis* Linn. and *Sesia bombyliiformis* Fab. (= *tityus* Linn.). The type is *tanialus* (Linn.) which is a sphingid now placed in the genus *Ellopos* Hübner. The genus *Ægeria* Fab. 1808 included the clear-wings or glassy-wings such as *Sphinx vespiiformis* Linn. (now *Synanthedon*), *Sphinx apiformis* Clerck (now *Ægeria*), and *Ægeria ichneumoniformis* S. and D. (now *Dipsosiphia*).

Stephens 1829 erected the family SESIIDÆ to include in general those species which had been named in the genera *Sesia*, *Sphinx* (in part), and *Macroglossa*; and the family ÆGERIIDÆ

may be entirely or only partly covered with scales, and frequently the hind pair and much of the fore pair are transparent. This characteristic, together with the slender form, rather long legs, and coloration, gives them the general appearance of several kinds of wasps. Even in flight certain species mimic wasps. The antennæ may be dilated apically and terminate in a bristle or tuft, rarely pectinate. Proboscis is well developed, slender, naked; maxillary palpi vestigial and porrect or absent; labial palpi acute, upturned; legs rather long, spurred, often with stiff tufts of hairs. Fore wings narrow, fully clothed with scales or partly transparent; accessory cell and base of medial absent; anal area greatly reduced, anal veins reduced; hind wings usually transparent except the margins; frenulum simple. Abdomen clothed with smooth, closely appressed scales and hairs, six-segmented in female and seven-segmented in male; male with conspicuous anal tuft. Eggs oval, flattened, reticulated. Caterpillars cylindrical, white or pale, wrinkled; with small inconspicuous setæ, five pairs of prolegs, each of the four median pairs with two transverse rows of crochets, the anal pair with a single row. They live as borers in roots, trunks, crowns, and limbs of woody shrubs and trees. Pupæ free with two rows of dorsal spines, last segment with ventral spines; skin partly withdrawn from cocoon upon emergence of adult.

The adults are very beautiful moths which are either weak or strong fliers and may often be seen resting upon the leaves, limbs, and trunks of trees or hovering about the hosts. The eggs are scattered on the bark of the trunks, limbs, and crowns. The larvæ feed in the crowns and small twigs or under the bark of trunks and larger limbs. A number of species are serious pests of wild and cultivated plants. Pupation occurs in a cocoon constructed of silk, frass, and refuse within, at the entrance of, or just outside the burrows.

The family is a relatively small one and is well represented in the forested areas of the tropical and temperate regions. The taxonomy of the family is in a state of some confusion owing to a lack of agreement concerning the genera and the species included. The most important genera and species are *Ægeria* Fab.: *A. apiformis* (Clerck), 15–20 mm. expanse, black and brownish with yellow markings on the head and thorax and yellow bands on the reddish abdomen. The larvæ infest chiefly poplars and willows throughout much of Europe, Asia, and North America. *Bembicia* Hübn.: *B. hylæiformis* (Laspeyres) (Palearctic) and *B. marginata* (Harris) (Nearctic) are common species, the larvæ of which bore into the stems of berries, *Rubus* spp. *Chamæsphecia* Beutenmüller is a large and important genus.

DÆ to embrace those species named in the genera *Ægeria* and *Synanthedon*. A study of these various genera and species indicate that the family SESIIDÆ was intended to embrace certain clear-winged moths now generally included in the family SPHINGIDÆ, and it should therefore be considered a synonym of the latter, whereas the *ÆGERIIDÆ* holds precedence as the proper family name for the clear-winged or glassy-winged moths. This latter name has been accepted by such authorities as Busck 1909, Rothschild 1911, Le Cerf 1911–1929, Holland 1913, Barnes and McDunnough 1917, Hampson 1919, Zukowsky 1921–1929, Forbes 1923, Dalla Torre and Strand 1925, Tillyard 1926, Gæde 1929, Seitz 1930, Matsumura 1931, Brues and Melander 1932, and Hering 1932. The arrangement of species is that of Dalla Torre and Strand.

Conopia Hübner is represented by the two important North American peach tree borers of which *C. exitiosa* (Say), metallic dark blue with yellow markings

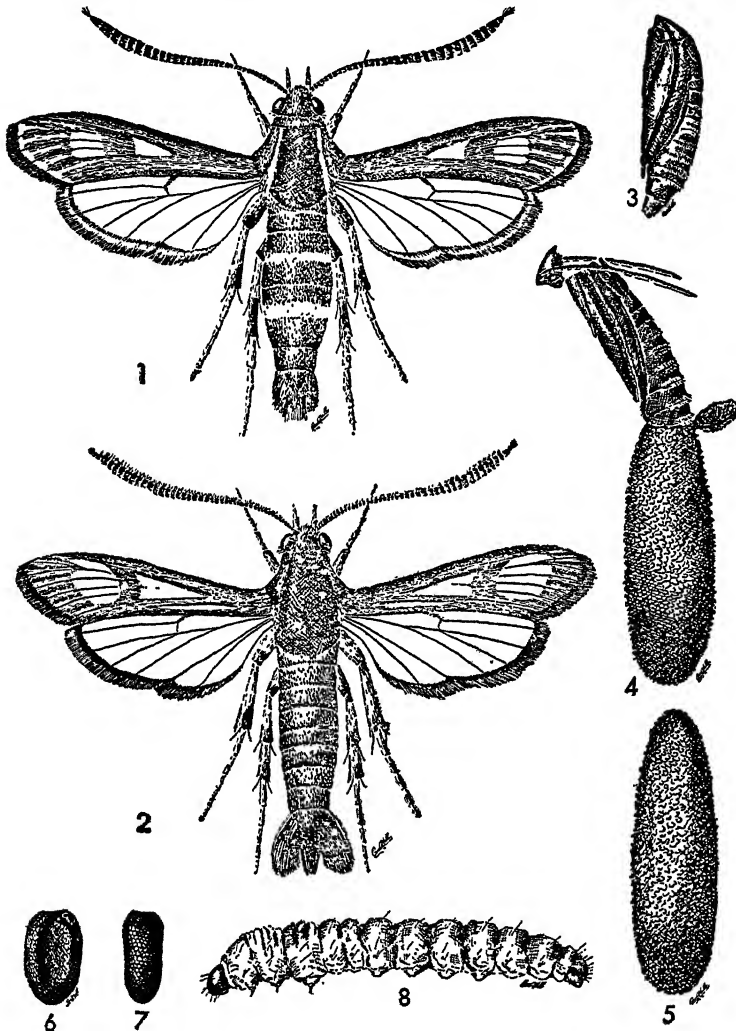


FIG. 148. The strawberry crownborer, *Synanthedon bibionipennis* (Boisduval). 1, female; 2, male; 3, pupa or chrysalis; 4, cocoon and exuvia of chrysalis; 5, cocoon; 6 and 7, eggs; 8, mature caterpillar. (After Mote, Wilcox, and Hills, 1929.)

on the male and a conspicuous orange-red median band on the abdomen of the female, is the common eastern species, while *C. opalescens* (Hy. Edwards) is a somewhat larger species, dark metallic blue: the male being marked with yellow

and the female wholly dark blue. *Dipsosphesia* Spuler, *D. ichneumoniformis* Schiffermüller and Denis of Europe and *D. mellinipennis* (Bdv.) of North America are important species.

Melittia Hübner is well represented in tropical Africa, Indo-Malaysia, Japan, South America, and North America, there being 101 described species. The squash borer, *M. cucurbitæ* (Harris) ranges throughout eastern North America, the larvæ boring into the stems of wild and cultivated cucurbs. *M. gloriosa* Hy. Edw. is a beautiful large black, brown, yellow, and reddish species infesting manroot in southwestern United States. *M. satyriniformis* Hbn. is Central and South American.

Paranthrene Hübner (*Memythrus* Newman) contains the common *P. polistiformis* (Harris), attacking the roots of grapes, and *P. robinia* (Hy. Edw.), a pest of locusts and poplars in various parts of North America, the latter being especially widespread. *Parharmonia* Beutm. has *P. picea* Dyar infesting spruce in the northwest and *P. pini* (Kellicott) attacking pines and spruces in the northeastern states. *Podosesia* Moschler is represented by *P. syringæ* (Harris), infesting ash and lilac in middle and eastern North America.

Sannina Walker, *Sciapteron* Staudinger, *Sphecodes* Hampson, *Sphecia* Hübner, and *Synanthedon* Hübner (*Trochilium* Scopoli) are widespread important genera. The last named is the largest genus with 201 described species, many of which are known to be serious pests of wild and cultivated trees and shrubs. The most important and widely distributed species in the family is *Synanthedon tipuliformis* (Clerck), commonly called the currant and gooseberry borer. It is widely distributed in Europe, Asia, and North America and has been introduced into Australia and other parts of the world. The larvæ bore in the stems of wild and cultivated currants and gooseberries. *S. culiciformis* (Linn.) and *S. vespiformis* (Linn.) attack many kinds of deciduous trees and shrubs in Europe. The lesser peach-tree borer, *S. pictipes* (Grote and Robinson), is a pest of peach and related members of the genus *Prunus* in eastern North America, while *S. bibionipennis* (Bdv.) (= *rutilans* Hy. Edw.) is the common strawberry crownborer of the Pacific coast. A study of the family indicates that certain genera may be arranged as feeding on the roots, trunks, limbs, and in the galls of other insects on a large number of deciduous shrubs and trees; on herbaceous perennials; on succulent annuals; and under the bark of conifers.

Family HELIODINIDÆ Wocke 1877 (He'li-o-din'i-dæ, from the Greek ἥλιος-ειδής, like the sun; referring to the brilliant metallic colors of some of these moths). Sun Moths.

A small family of minute moths which may be very inconspicuous or brilliantly marked. According to Forbes (1923) the most characteristic feature of the members is the resting position, the middle or hind legs being conspicuously raised or extended laterally. The minute caterpillars are either herbivorous or predacious and it appears that certain species may be both. Plant-infesting forms mine the fruit or foliage or feed in galls, seeds, or fruits while predacious

species have been observed feeding near or on mealybugs, unarmored scales, and other coccids. Pupation occurs in a thin silken cocoon which is lace-like in *Schreckensteinia*. The larvæ of most of the described species are still unknown.

Certain species in the genera *Augasma* H.-S., *Calicotis* Meyrick, *Cycloplasis* Clemens, *Heliodines* Stainton, *Idioglossa* Walsingham, *Schreckensteinia* Hübner, and *Scelorthus* Busck are known to be plant feeders while those of *Euclemensia* Grote, *Ædematopoda* Zeller, and *Stathmopoda* Stainton are reported as predacious on coccids. Certain species in the latter predacious genera are also known to be herbivorous.

Family YPONOMEUTIDÆ¹ Stephens 1829 (Y'po-no-meut'i-dæ, from the Greek *ὕπονόμεω*, to mine; referring to the mining habits of the larvæ). Beautiful Mining Moths.

Small moths with expanse of 12–25 mm.; often strikingly and beautifully colored. Head smooth or with anterior tuft. Ocelli very small or absent. Mouth parts poorly developed; maxillary palpi vestigial or absent; labial palpi variable, thin, smooth. Metathorax very large; scutum undivided. Wings rather wide; fore pair with stigma, rounded margin, and large accessory cell; hind pair almost as large as fore wings and with short fringe or lanceolate and without fringe; *M*₃ absent. Eggs usually somewhat flattened. Caterpillars naked; prothoracic prespiracular wart with three setæ; primary setæ only present; crochets of prolegs in several complete circles; living singly or gregariously in webs. Pupæ obtect; abdominal spiracles tubular and extended; cremaster represented by four setæ; enclosed in cocoons.

This is a medium-sized family well represented throughout the world. Certain species are quite destructive to conifers and to evergreen and deciduous trees and shrubs. Many species are gregarious and free-living on the foliage while others are miners in leaves, twigs, and fruits. The most important widely distributed genera are *Argyresthia* Hübner, *Attana* Walker, *Lactura* Walker, *Prays* Hübner, *Swammerdamia* Hübner, *Urodes* Herrich-Schaffer, *Yponomeuta* Latr., and *Zelleria* Stainton.

(9) Superfamily GELECHIOIDEA Mosher 1916

KEY TO IMPORTANT FAMILIES

1. Radius and first medial vein of hind wings close together or stalked 2
 Radius and first medial vein of hind wings widely separate at base, at
 least half as far apart as at the margin. 4
2. Hind wings lanceolate (tapering towards base and apex), narrower than
 the fore wings; with cubital pecten. Tiny moths often with metallic
 markings COSMOPTERYGIDÆ
- Hind wings not lanceolate, wider than fore wings 3
3. Fore wings with the fourth and fifth radial veins stalked; hind wings
 trapezoidal and usually wider, strongly rounded out at the end of the

¹ HYPONOMEUTIDÆ of many authors is incorrect since the type genus is *Yponomeuta* Latreille and not *Hyponomeuta*.

third medial and first cubital. Larvæ leaf miners, leaf rollers, and stem, root, and seed feeders; some serious pests. Tiny or small moths **GELECHIIDÆ**

4. Second radial vein arising at the apex of the cell; third medial and cubitals also closely crowded from lower angle; five radials extending to costa; male usually with strong sexual modifications. Small obscure moths **BLASTOBASIDÆ**

Second radial arising distinctly before the apex of the cell, well away from the origin of the third radial 5

5. Five veins extending from the cell to the costa in the fore wings. 6
Four veins extending from the cell to costa in the fore wings, the fifth radial ending decidedly below the wing-tip 7

6. Second branch of media of hind wings arising decidedly nearer to the first than the third medial; wings relatively broad, fore pair often brightly colored. Larvæ gregarious, web spinners **ETHMIIDÆ**

Second medial vein of hind wings arising nearer the third medial, or rarely midway between the first and third; fourth radial vein of fore wings stalked; ocelli vestigial or absent; head scaled; maxillary palpi vestigial or absent; labial palpi long, porrect; antennæ usually with basal pecten. Larvæ with variable habits, often case makers

CECOPHORIDÆ

Family GELECHIIDÆ Stainton 1854 (Ge-lech-i'i-dæ, from the Greek *γηλεχής*, sleeping on the earth; because the adults of many species rest on the ground). Gelechiid Moths.

Minute to small, cryptic and brightly colored, diurnal, crepuscular, and nocturnal moths. Head smooth or ruffled. Proboscis moderately long and

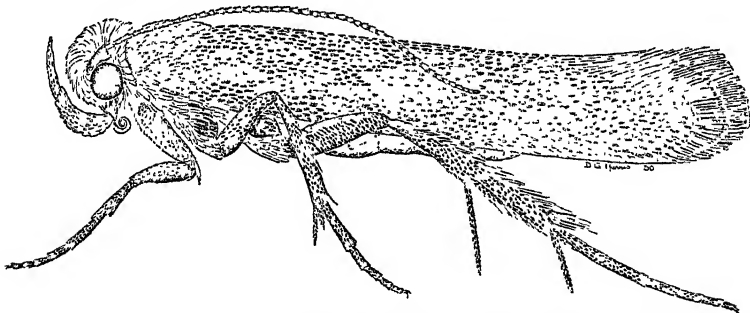


FIG. 149. The potato tuber moth, *Gnorimoschema operculella* (Zeller), a small moth widely distributed by commerce. (From *A History of Entomology*.)

scaled basally. Antennæ rarely with basal pecten. Maxillary palpi vestigial or absent. Labial palpi slender, long, upturned, acute. Hind tibiae rough-haired. Wings with the vein A_1 either absent or rarely represented by the extreme tip. Fore wings usually narrower than the hind wings; R_s extending into C and stalked with R_4 . Margins of hind wings often concave and emarginate with pointed tips. Larvæ cylindrical, pale or pinkish, naked; ocelli evenly spaced

on each side; prolegs absent or present; anal crochets in two groups. They are largely herbivorous and may spin webs. Pupation is within a silken cocoon.

This is a relatively large family of some 400 genera and 3,700 species, widely distributed throughout the world. Among the most interesting and important species is the **Angoumois grain moth**, *Sitotroga cerealella* (Olivier), pale yellow, expanse 20–25 mm., a European species the tiny larvæ of which feed in the kernels of barley, corn, sorghum, wheat, and other cereals. Infestation may occur in the field or in storage and continues until the cereals are virtually destroyed. It has been widely distributed in commerce and was the first economic insect discussed in print in North America as infesting wheat in Virginia in 1771, although known to occur in the Colonies prior to 1743.

Another very important and cosmopolitan insect is the **potato tuber moth**, *Gnorimoschema operculella* (Zeller) (*Phthorimæa*), a small tan and dark-speckled moth which is a serious pest of potatoes and also infests tomatoes and other solanums. The larvæ work as miners in the leaves and as burrowers in the tubers of potatoes and the fruits of tomatoes. It was first discovered as a pest of potatoes in Tasmania in 1854 and subsequently in California in 1856. It was described in 1873 from adults collected in Texas (Graf, 1917). It now occurs in many subtropical and warmer temperate areas where its hosts occur. The **tomato pinworm**, *Keiferia lycopersicella* (Busck), is a pest of considerable importance to tomatoes in middle and southern California. The **goldenrod gall moth**, *Gnorimoschema gallæsolidaginis* (Riley), is a common species in eastern North America. Members of the genus *Recurvaria* Haworth are needle miners of coniferous trees. *R. milleri* Busck is a very serious pest of lodgepole pine in the Sierra Nevada mountains of California. The **peach-twig borer**, *Anarsia lineatella* Zeller, is a European species which has become very widely distributed throughout the temperate regions and is a major pest of fruit and ornamental trees belonging to the genera *Prunus* and *Pyrus*. It is possible that the insect may have been introduced into Europe from Asia. The **pink bollworm**, *Platyedra gossypiella* (Saunders) (*Pectinophora*), is one of the world's worst pests of cotton. It first attracted attention as a pest in India in 1842 in which year it was described. Since then it has been noted in Egypt and Mexico in 1911, in Brazil in 1915, and in Texas in 1917. It is now distributed throughout much of the cotton-growing area of the world.

(10) Superfamily ELACHISTOIDEA

KEY TO IMPORTANT FAMILIES

1. Hind wings with discal cell. **ELACHISTIDÆ**
 Hind wings without discal cell. 2
2. Vein R_s of hind wings branching from M near middle of length of wings **DOUGLASHIDÆ**
 Vein R_s of hind wings branching from M near apex of wings **HELIOZELIDÆ**

(11) Superfamily TORTRICOIDEA McDunnough 1939

KEY TO IMPORTANT FAMILIES

1. Hind wings with M_1 and often also M_2 absent 2
 Hind wings with M_1 present or rarely absent, in which case the wings
 are emarginate. 3
2. Hind wings with cell closed, M_1 and M_2 absent, R_s unbranched, outer
 edge not emarginate; fore wings conspicuously tufted, all branches
 of R free, R_s extending to apex, A_1 absent; labial palpi often long.
 Larvæ feed on foliage and fruits and some produce galls. Adults
 small. Nearctic, Oceanic, and Australasian CARPOSINIDÆ
 Hind wings somewhat trapezoidal, cell open, M_1 and often M_2 absent;
 fore wings with R_s absent. Ethiopian and Oriental

METACHANDIDÆ

3. Fore wings with Cu_2 arising before the last fourth of cell; labial palpi
 moniliform, segment III short and truncate, segment II smoothly or
 roughly scaled and porrect or oblique 4
 Fore wings with Cu_2 arising near apex of cell; labial palpi beak-like, seg-
 ment II rough scaled dorsally and smooth on inside; segment III
 porrect and small; fore wings with A_1 absent, all veins arising sep-
 arately from cell; hind wings with R and M_1 close together or stalked
 and distant from M_2 , A_1 absent, cubital pecten present. Larvæ web
 spinners and borers. Adults small. Widely distributed and chiefly
 Holarctic, few Australian. (Phaloniid Moths.) . . . PHALONIDÆ
4. Fore wings with R_3 and R_4 stalked or coincident; hind wings with M_2
 and M_3 parallel, R_s and M_1 stalked. Indo-Australasian

CHLIDANOTIDÆ

Fore wings with R_3 and R_4 separate or rarely stalked; hind wings with
 M_1 and M_2 both absent. Larvæ leaf rollers and leaf, bud, and fruit
eaters. Adults mostly somber-colored. Cosmopolitan. (Leaf Rollers,
Bell Moths.) TORTRICIDÆ p. 462

Family OLETHREUTIDÆ ¹ Walsingham 1900, 1913 (O'le-threut'i-dæ, from
the Greek *ὄλεθρος*, destruction, ruin; because of the damage to plants by
the caterpillars). Leaf Rollers.

The members of this family are mostly small, finely scaled, somber- and
cryptic-colored moths, usually tan, brown, or gray with mottlings, bands, and
rarely metallic areas. Labial palpi well developed; second segment with closely
appressed rough scales; third short and blunt; porrect and beak-like. Fore
wings with Cu_2 arising before the last fourth of the discal cell. Hind wings
usually with cubital pecten; radial vein not forked at apex.

The moths are quite variable in general appearance and habits but are mostly
crepuscular and nocturnal. The eggs, which may be of a number of shapes,
are very minute and are usually laid singly on the fruit and foliage of the host

¹ Synonyms: EUCOSMIDÆ Durrant 1918, GRAPHOLITHIDÆ Cotes 1889.

plants. The caterpillars are small, active, smooth, with setæ and hairs and some with basal tubercles and light or pigmented areas; white, yellow, pink, or various shades of green in color. They are chiefly foliage and fruit and nut feeders. Those on the foliage frequently roll the leaves and web them together in compact masses. Fruit feeders destroy the pulp or the seeds while certain nut-infesting forms feed in the outer hull or jacket or invade the interior and destroy the kernel. As a group they are very injurious to wild and cultivated plants alike, and large expenditures are necessary to lessen and control their depredations.

The taxonomy of this and related families is in a flux, and there is apparently much yet to be done before complete order is secured. Many of the genera included in this family have previously been placed in the family TORTRICIDÆ and there is yet no common agreement as to the name of this particular group. The family is a large one containing several thousand species which are widely distributed throughout the world. It is especially well represented in the temperate forested areas, but many species also occur in the partly wooded plains and cultivated regions. Only a few of the very many important species can be included.

The most injurious and important economic species is the **codling moth**, *Carpocapsa pomonella* (Linn.) (*Cydia* Hübner, *Olethreutes* Hübner), a European species widely distributed throughout the world, now coextensive with cultivated pome fruits and introduced into the United States prior to 1819. The adults have a wing expanse of 15-22 mm. and are bluish-gray in color, harmonizing well with the gray bark of the host plants. The fore wings are brownish with several gray or paler cross lines, and near the tip of each is a coppery spot in which are two irregular golden lines; the hind wings are paler with fringed borders. The eggs are disk-like and about the size of a pinhead, transparent white when first laid and becoming reddish and dark with the development of the embryo. The minute, newly hatched larvæ are whitish with large black heads. When mature they are white, yellow, or pinkish, with the head, shield, and anal plate brown; nearly naked or with a few hairs arising from areas of minute pigmentation, clearly visible with a hand lens; they attain a length of from 25-35 mm. Pupation occurs in a white felty cocoon in any convenient place on the trees or other objects. The pupa is about 13 mm. in length and varies from yellow to dark brown. The species is from two- to four-brooded depending upon the latitude. The winter is passed in the larval stage within the cocoons on the trees in such protected places as under the bark, in wounds, crotches, in hollow stems of weeds, among grasses, or in litter on the ground; or in boxes, storehouses, or other protected places. In the spring the larvæ enter the pupal stage, which requires approximately 20 days. The first moths emerge about the time the apples begin to leaf out and bloom, and various generations continue to appear at intervals until harvest. The first eggs are laid mainly on the leaves and twigs and a few on the very young fruit, while those of succeeding generations are usually placed on the green fruit. The larvæ of the first brood feed largely on the leaves while those follow-

ing enter the fruit from the calyx end or sides. About 20 days are required for the development of the caterpillars and about 50 days for a complete life cycle. In the west there are two or three broods in much of the range with a partial fourth in the southern areas. The injury to the fruit of apples and pears by the larvæ or worms is familiar to all and consists in one or several holes through the skin and a mass of frass about the core. Crab apples, apricots, cherries, loquats, peaches, plums, haws, and similar fruits are also occasionally attacked. The green nuts of English walnuts are also commonly and often seriously infested in southern Europe and in California. There are very many natural enemies of the codling moth, but their combined efforts are of little avail in checking the pest under orchard conditions. For more than fifty years the codling moth has received as much attention from professional entomologists as any other insect pest of agricultural crops.

A very interesting closely related species is the **Mexican jumping bean moth**, *Laspeyresia saltitans* (Westwood). The larvæ inhabit the thin-walled seeds of *Sebastiania* spp., and, when the kernel is consumed, throw themselves forcibly against one side, causing the very light shell to jump considerable distances. In nature this is perhaps a means of finding suitable places of concealment during the pupal stage which occurs within the protective shell. A very serious and recent pest of deciduous fruit trees is the **Oriental peach moth**, *Grapholitha molesta* (Busck) (*Laspeyresia*), an Asiatic species which has become widely distributed by commerce until it now occurs in all the continental areas with the possible exception of Africa. It was introduced into the United States in 1916 at Washington, D. C., and now occurs in certain areas east of the Rocky Mountains. The **pea moth**, *Grapholitha nigricana* (Stephens), of Europe is now also a pest of much importance to peas in western Canada. The **lesser apple worm**, *G. prunivora* Walsh (*Laspeyresia*), and the **clover seed worm**, *Ecadytolopha interstinctana* (Clemens), are important in eastern North America. The **strawberry leaf folder**, *Ancylis comptana* Froehl,¹ is a European species introduced into and now widespread in much of North America. The **grape berry moth**, *Polychrosis vileana* (Clemens), is a serious pest of the American vine in eastern North America whereas *P. botrana* (Schiffmüller) is equally injurious to the European vine in middle and southern Europe. The **cranberry blackhead fireworm**, *Rhopobota nævana* Hübner, is a European species attacking bilberry, hawthorn, and other plants in Europe which has become a serious pest of cranberries in North America, where it also feeds on a number of shrubs. The **acorn moth**, *Melissopus latiferreanus* (Walsingham), is not only a very injurious pest of acorns but also infests other seeds, fruits, and even oak galls in North America. The **bud moth**, *Spilonota ocellana* (Denis and Schiffm.), is an important orchard pest both in Europe and North America. Larvæ of the members of the genera *Rhyacionia* Hübner, *Petrova* Heinrich, *Barbara* Heinrich, and *Zeiraphera* Treitschke feed on the needles or on the twigs, limbs, or cones of coniferous trees.

¹ This and a number of the following species are placed in the family TORTRICIDÆ by many authors. I am following Brues and Melander (1932).

Family TORTRICIDÆ ¹ Stephens 1829 (Tor-tric'i-dæ, from the Latin *torquere*, *torum*, to twist; because the caterpillars twist and roll the leaves and tie them with silk webbing). Tortricids, Leaf Rollers, Bell Moths.

Small, closely scaled, active, mostly nocturnal moths which are cryptically colored: tan, brown, gray, and often striped, spotted, or marbled; rarely with more than 30 mm. expanse. When folded, the wings are more or less bell-shaped in many species. Antennæ usually not longer than the fore wings. Maxillary palpi three-segmented or vestigial. Wing membrane smooth. Fore wings with first radial rarely as strong as other veins, separated from the base by several times its length. Hind wings with first branch of media present. The eggs, of many different shapes, are frequently laid in shingled masses (*Pandemis*) and may be covered by a waterproof cement (*Tortrix*). In the latter case they are laid in summer or fall and the larvæ may develop and hibernate in the shells, emerging early the following spring. The caterpillars of many species are various shades of green with scattered hairs arising from small pale papillæ. Some wriggle violently and may escape backwards through their nests of rolled leaves and drop on a silken thread. Pupation is in the rolled leaves or in cocoons spun in debris or under the bark scales or in cracks and scars on the host plants.

This is a fairly large family of destructive species which frequent forested areas and attack all kinds of trees, shrubs, and herbaceous perennial plants. While it is well represented in the temperate regions it appears to reach an unusually high degree of development in Australia, where some 300 species are known (Tillyard 1926). The most important genera are *Acalla* Hübner, *Amorbia* Clemens, *Cacacia* Hübner, *Chrosis* Hübner, *Eulia* Hübner, *Harmologa* Meyrick, *Sparganothis* Hübner, *Tortrix* Linn., and *Archips* Hübner.

Tortrix excessana Walker is a pest of apples in New Zealand, and *T. postvittana* Walker is a pest of apples in Australia and New Zealand. Perhaps the most important destructive species is the spruce bud worm, *Harmologa fumiferana* (Clemens), which is a serious pest of balsam fir, spruce, hemlock, larch, and white pine in northeastern North America. In some areas the trees may be completely defoliated and killed by the caterpillars which are able to swing from tree to tree by spinning a silken thread. The fruit tree leaf roller, *Tortrix argyrospila* (Walker), at times defoliates fruit trees in many parts of North America. The orange tortrix, *Argyrotaenia citrana* (Fernald) *Eulia*, *Tortrix*, infests the fruit of oranges, but the larvæ also feed on a variety of wild and cultivated plants, fruit trees, and even pines in California. It is also recorded in Brazil.

(12) Superfamily PTEROPHOROIDEA Tillyard 1926

KEY TO FAMILIES

1. Wings deeply cleft or divided into plume-like divisions; legs long.
(Plume Moths.) 2

¹ Many genera and species formerly included in this family are now separated off into the family OLETHREUTIDÆ.

Wings entire or rarely with the fore pair somewhat cleft; ventral surface of hind wings with two series of enlarged divergent scales along the cubital vein; tibiae and spurs long AGDISTIDÆ

2. Wings two- to four-cleft 3
Wings six-cleft; small silvery-white moths ORNEODIDÆ

3. Fore wings two- to four-cleft; hind wings three-cleft. Larvæ burrow into stems and seed heads of plants. Moths small, delicate, and variably colored, but mostly rather somber. (Plume Moths.)

PTEROPHORIDÆ

All wings two-cleft. Small oriental and Australian family

OXYCHIROTIDÆ

Family PTEROPHORIDÆ Zeller 1841 (Pter'o-phor'i-dæ, from the Greek *πτεροφόρος*, feathered; referring to the divided feathered or plumed wings). Plume Moths.

Small, mostly pale-grayish or brownish slender moths, usually with remarkable two- or three-cleft wings which are frequently fully expanded at rest. A few species have the wings entire whereas normally the fore pair may be three-cleft and the hind pair two- or three-cleft.¹ Maxillary palpi are absent. The caterpillars are variable, being either relatively smooth or spiny. They are leaf rollers and stem borers, and some are of economic importance as pests of ornamental and agricultural plants. The pupæ are spiny, with prominent pilifers or lateral processes of the labrum. The adults are diurnal, crepuscular, and nocturnal. The family is small but well distributed, though little systematic and biological work has been done on it. The most widely distributed species are the almost cosmopolitan *Stenoptilia zophodactyle* Duponcel, on centaury and yellow wort, and *Sphenarches caffer* Zeller on *Dolichos* in Africa, India, Australasia, and the Pacific Ocean.

(13) Superfamily PYRALIDOIDEA Mosher 1916

KEY TO IMPORTANT FAMILIES

1. Hind wings with Cu vestigial or absent 2
Hind wings with Cu present 3
2. Fore wings with M_2 , when present, arising equidistant from M_1 and M_3 , with a single anal vein; with all veins separate; hind wings with two anal veins; maxillary palpi usually present. Small family of Australian and Indian moths TINEODIDÆ

Fore wings with M_2 always present and arising near M_3 ; all veins arising separately; maxillary palpi minute or absent. Larvæ burrow in twigs and stems and cause gall-like swellings. Moths mostly small, brownish in color, and often with translucent white and yellow areas in the wings; mostly tropical THYRIDIDÆ

¹ Members of this family that have the fore wings three-cleft and the hind pair two-cleft are called five-plume moths whereas those species having six- to 12-cleft wings are placed in the family ORNEODIDÆ, and the Australian species with all wings two-cleft in the family OXYCHIROTIDÆ.

3. Hind wings without cubital pecten or comb of stiff hairs . . . 4
 Hind wings with stiff cubital pecten 6
4. Proboscis present 5
 Proboscis vestigial or absent; maxillary palpi present; labial palpi porrect. Larvæ burrow in sedges and rushes. Small or large Australian moths **SCHENOBIIDÆ**
5. Fore wings with R_5 separate, R_3 and R_4 stalked; maxillary palpi small or clothed with scales; labial palpi porrect. Larvæ with variable habits, many very destructive to crops. Small somber-colored moths **PYRAUSTIDÆ**
 Fore wings with R_5 stalked with R_3 and R_4 ; R_1 much shorter than the cell. Larvæ with wide diversity of habits. Many are serious pests to crops and stored products. Moths small and somber-colored. A very large family. (Pyralid Moths, Snout Moths.) . . . **PYRALIDIDÆ** p. 465
6. Fore wings usually with R_5 present 7
 Fore wings with R_5 absent; hind wings with cell closed by a delicate and nearly entire vein; frenulum of female a single spine; proboscis well developed. Larvæ mostly leaf rollers or grass feeders. Some are serious pests of stored food products. Adults small and dull or handsome. (Grass Moths, Meal or Flour Moths.) . . . **PHYCITIDÆ** p. 467
7. Labial palpi long and equal in both sexes; maxillary palpi triangularly scaled; labial palpi moniliform; hind wings with cell wide open and with a thick fringe; frenulum of female multiple. Larvæ live largely on grasses, feeding at the bases of the plants. Adults mostly small and extremely variable in color. (Grass Moths, Crambid Moths.) . . . **CRAMBIDÆ** p. 465
 Labial palpi short in male, long in female; maxillary palpi not triangularly scaled; proboscis and ocelli absent; front of head with conical tuft; vestiture usually mixed. Larvæ mostly scavengers in the nests of social bees and wasps or on dried products. (Bee Moths.) . . . **GALLERIIDÆ** p. 466

Family PYRAUSTIDÆ (Smith 1891), Meyrick 1896 (Py-raus'ti-dæ, from the Greek *πυρὰστρος*, a fabulous insect living in fire). Leaf-tiers, Webworms.

Moths very similar to those of the family PYRALIDIDÆ, from which they are separated by the small, slender maxillary palpi which are rarely dilated by scales; the porrect and upturned labial palpi; and veins $R_3 + 4$ and M_1 rarely separated. The family is a fairly large one with a number of important species.

The European cornborer, *Pyrausta nubilalis* Hübner, a pale brownish-yellow, flecked species, 12–15 mm. long, was introduced into North America on broom corn and discovered near Boston, Massachusetts, in 1917. The larvæ bore in the crowns and stalks of maize, sorghum, millet, hemp, and a large number of other plants. Its attacks on maize were very greatly feared, and a special appropriation of \$10,000,000 was voted by Congress in 1927 for the suppression of the insect, but the insect was not exterminated and has gradually spread westward to the Mississippi River.

The garden webworm, *Phlyctænodes similalis* Guenée (*Loxostege*), is a common economic species in North and South America, while *P. sticticalis* (Linn.)

occurs in Europe and North America. There are many other Holarctic species. The **grape leaffolder**, *Desmia funeralis* (Hübner), is a small black moth with conspicuous white spots on the wings. The larvæ roll the leaves of grapes upon which they feed and may defoliate large vineyards. This European species is widely distributed in North America. The **celery leaf-tier**, *Phlyctania ferrugalis* Hübner, is a pest of celery in southern North America but also feeds upon a wide variety of plants. It is Holarctic in distribution. The **melonworm**, *Margaronia*¹ *hyalinata* (Linn.), a beautiful white and black moth, and the **pickleworm**, *M. nitidalis* (Cramer) are destructive to the vines of cucurbs in North and South America and *Phakellura indica* Saunders feeds on cucurbs in Australia. The **imported cabbage webworm**, *Hellula undalis* (Fab.), is a widely distributed Old World species now common in certain parts of the southern United States. The truly aquatic larvæ of the Australian *Hydreuretis tullialis* Walker have filamentous tracheal abdominal gills and live in cylindrical cases made of reeds (Tillyard, 1926).

Family PYRALIDIDÆ² Leach 1815, 1819 (Py'ral-id'i-dæ, from the Greek πυραλίδος, a winged insect supposed to live in fire). Pyralids, Snout Moths.

Small, mostly somber and cryptic moths with closely appressed scales. Antennæ well developed and tapering to a point. Ocelli and proboscis present; maxillary and labial palpi well developed and often forming what appears to be a snout. Wings with long frenulum and without pecten; fore wings with R₁ as long as or longer than the cell; hind wings with Sc free or fused with Rs beyond the cell. The larvæ are naked and with primary setæ arising from plates or small tubercles; thoracic legs present; prolegs variable and always present on segment VI; crochets uni-, bi-, or triordinal and in parallel rows; prespiracular prothoracic tubercle bisetose. Chrysalis obtect and in a thin cocoon. The members of this family are largely phytophagous, and many of them feed upon dried vegetable matter, including botanical specimens, hay, and cereals.

The most important species is the **meal moth**, *Pyralis farinalis* (Linn.), a small golden moth with dark flecks on the fore wings. The caterpillars feed on cereals, cereal products, and dried vegetable debris. It is a cosmopolitan species. The **clover hayworm**, *Hypopygia costalis* (Fab.), feeds on dried clover hay in Europe and North America. The larvæ of *Nymphula nymphæta* (Linn.) and *N. stagnata* Donovan are semiaquatic species living in silk or silk-lined sacs on water plants in Europe.

Family CRAMBIDÆ Duponcel 1844 (Cram'bi-dæ, from the Greek κράμβος, dry, withered; in reference to the drying-up of grasslands owing to the feeding of the larvæ). Grass Moths, Snout Moths, Grass Webworms.

Small, slender, finely and closely scaled moths which are commonly silvery, whitish, pale and brown, or grayish in color. They abound in grasslands and

¹ Other generic designations are *Eudiotis* Hübner, *Diaphania* Hbn., *Phakellura* Poey, *Glyphodes* Guenée.

² PYRALIDÆ of authors. Many groups have been separated from this family into distinct families.

also occur in fields of sugar cane, corn, sorghum, rice, and other cereal crops. The moths are crepuscular or nocturnal but take short, erratic flights during the day if disturbed. Antennæ simple or pectinate. Ocelli usually present and often prominent. Proboscis present; variable in length; maxillary palpi long and triangular; labial palpi long and straight and together form a snout-like protuberance. Tibiæ spurred. Wings smooth-scaled. The eggs are laid on the hosts or dropped over the grasslands. The larvæ are cylindrical, pale whitish, yellowish, pinkish, or very dark reddish-brown, with series of hair-bearing body tubercles. They live secluded either as borers in the crowns and stems of monocotyledonous plants or at the bases of the roots, and in some cases a considerable amount of webbing occurs in the burrows in the soil and plants and about the crowns and the tops of the hosts, which has given rise to the name webworms. The family is a fairly large one and is in need of much study both systematically and biologically. It is specially abundant in grasslands and wherever cereals and grasses grow. The most important genera are *Chilo* Zinchen, *Crambus* Fab., and *Diatræa* Guiling.

Perhaps the most important destructive species is the oriental rice borer, *Chilo simplex* Butler, which causes great losses to the rice crop in southern and eastern Asia. The sugar-cane borer, *Diatræa saccharalis* (Fab.), first came into prominence as a pest of sugar cane in the West Indies in 1828 and has been a pest of that host in the United States since 1855. It is also destructive to maize, sorghums, and rice and has a wide distribution in tropical and subtropical America. *D. sticticraspis* (Hampson) and *D. venosata* (Walker) are the common sugar-cane borers of India and the Orient. *D. zeacolella* Dyar is the lesser corn-stalk borer of eastern and southern United States and Mexico. Members of the genus *Crambus* are exceedingly numerous and, while they are largely feeders on grasses, cereals, and other GRAMINEÆ, a considerable number are pests of many other kinds of plants. Grass-feeding forms are often very destructive to lawns and golf greens.

Family GALLERIIDÆ (Zeller 1848), Wallengren 1871 (Gal'ler-i'i-dæ, from the Middle Latin and Italian *galeria*, a long portico, a gallery, applied to a narrow passage and perhaps referring to the burrows of the larvæ). Wax-moths, Beemoths, Waxworms.

Small to medium-sized, inconspicuous tan or grayish, stout, nocturnal moths which, though often abundant, are not commonly noted. Antennæ of male simple. Ocelli absent. Proboscis vestigial or absent. Maxillary palpi small in female and obsolete in male. Labial palpi long in female and short and hidden in male. Fore wings with R_3 - R_5 stalked. Hind wings with well-developed cubital pecten; frenulum multiple in female and simple in male. Larvæ pale and relatively naked; prespiracular prothoracic setæ present; crochets of pro-legs uni- or biordinal and in an ellipse; scavengers or inquilines in nests of bees and wasps or saprophagous on dried vegetable and rarely animal materials. Pupæ with well-defined appendages and somewhat spined; enclosed in a thick, tough cocoon.

These moths constitute a relatively small family, some species of which have been widely distributed in commerce. The most important is the beemoth or waxworm, *Galleria mellonella* (Linn.), gray or pale brown, expanse 25–30 mm., which inhabits the hives of the common honeybee. The pale and dark caterpillars feed upon the wax, through which numerous burrows are made. They also soil the honey with their frass. An interesting peculiarity of the adults, no doubt acquired through years of associating with the honeybee, is that during the day they remain motionless in the hives and when disturbed may make a short flight, only to become rigid immediately. This moth has been a pest of considerable importance in poorly kept apiaries throughout the ages and has become cosmopolitan with the honeybee. The lesser waxworm, *Achroia grisella* (Fab.), is an Old World species introduced into Australia and North America. The larvæ feed on wax in beehives and also on dried vegetable and animal products. *Corcyra cephalonica* Stainton feeds on dried vegetable and animal products in Australia. *Aphomia sociella* (Linn.) lives in the nests of bumblebees and wasps and also on dried vegetable products and refuse. It is a European species introduced into North America. *Tirathaba parasitica* Lucas larvæ live in the burrows of and are thought to be predacious on the larvæ and pupæ of hepialid moths in Australia. The Australian *Heteromicta latro* Zeller, expanse 30–45 mm., is one of the largest members of the family as now known.

Family PHYCITIDÆ¹ (Meyrick 1893) Ragonot 1893 (Phy-cit'i-dæ, from the Greek *phukos*, seaweed or *phukēs*, a fish living in seaweed; application uncertain). Phycitid Moths, Cereal and Dried Fruit Moths.

Minute to small moths which are very abundant in the tropics but are also well represented in the subtropical and warmer temperate regions. Sombre-colored but some with metallic coppery markings. Antennæ long, simple. Proboscis present or absent; maxillary palpi vestigial or well developed, alike in both sexes. Labial palpi well developed, porrect or ascending. Fore wings with R_2 absent. Hind wings with cubital pecten, a comb of stiff hairs developed on the base of the cubitus. The males may have one or two pairs of tufts on abdominal segment VIII. The larvæ are cylindrical, pale, with few setæ and hairs; chitinated, pigmented rings around seta IIb on mesothorax and seta III on abdominal segment VIII [absent in *Etiella zinckenella* (Treitschke)] (Heinrich 1939). They are external and internal feeders of stems, fruits, seeds, dried fruits, cereals, and cereal products.

Although relatively few members of the family are of economic importance, those that are known as such are among the most injurious pests because they destroy such large quantities of stored essential food products throughout the world. Under favorable storage conditions, the moths are able to feed and breed throughout much of the year in the temperate zones and may even develop indoors in the polar regions. The most important genera are *Acrobasis*

¹ Also spelled PHYCIDÆ. These moths are generally placed in the family PYRALIDIDÆ.

Zeller, *Anerastia* Hübner, *Cactoblastis* Ragonot, *Ephestia* Guenée, *Etiella* Zeller, *Myelois* Hübner, *Plodia* Guenée, and *Phycila* Curtis.

The Indian meal moth, *Plodia interpunctella* Hübner, is not only the most injurious member of the family but one of the most important economic insects known. The adults are 7-9 mm. long and have a wing expanse of 20 mm.; pale gray with the apical two thirds of the fore wings metallic coppery. Some forms are ochreous with the tips of the fore wings reddish-brown. The eggs are pearly white, oval, very minute, and laid singly or in small groups. Each female may deposit from 300 to 400 eggs. The caterpillars vary in color and are white, yellow, pink, or greenish with brown head and prothoracic shield. When mature they attain a length of 18-20 mm. They feed on cereals and cereal products, dried fruits, nuts, chocolate, and candies, and spin silken webs throughout and over these objects. Breeding continues during the entire year in favorable quarters, the life cycle requiring from 4 to 5 weeks. There are from four to seven broods annually. It is cosmopolitan in distribution and has been carried with commerce everywhere.

The Mediterranean flour moth, *Ephestia kuehniella* Zeller, expanse 24-26 mm., dark gray, is a cosmopolitan species found in flour mills, storehouses, stores, ships, residences, or wherever are found the cereals and cereal products upon which the larvæ feed. The chocolate moth, *E. elutella* (Hübner), the fig moth, *E. cautella* Walker, and the raisin moth, *E. figulella* Gregson, are all general feeders on stored vegetable food products and especially on cereals, nuts, and dried fruits. They are all practically cosmopolitan, having been carried to all parts of the world. Members of the genus *Anerastia* are grass moths in Australia. *Myelois venipars* Dyar may feed on injured or decayed tissues of oranges in Arizona. The bean pod borer, *Etiella zinckenella* (Treitschke), is a European species now widely distributed in North America and Japan, and *Fundella cistipennis* Dyar is a similar species. Both of them attack the developing seeds of beans, peas, and other legumes and are especially fond of lima beans in America.

The remarkable cactus moth, *Cactoblastis cactorum* (Berg) (*Zophodia*), has proved a very important beneficial species in the destruction and control of at least portions of 60,000,000 acres of cacti or prickly pears, *Opuntia inermis*, *O. stricta*, and other species which were introduced into Australia and took possession of vast areas in New South Wales and Queensland. In 1925, 2,750 eggs of this moth were collected in Argentina and sent to Australia for colonization. The moth at once became established, and the larvæ fed upon the cacti with such avidity and thoroughness that, with the aid of a fungus which followed its burrowings, the larvæ laid waste the obnoxious plants in large areas and with some aid from man are restoring the impenetrable cactus thickets to their original condition. As many as 300,000,000 eggs were collected and distributed throughout the area from 1927 to 1929 (Sweetman, 1936). The adults are whitish or ochreous with fuscous markings and an expanse of 25 mm. The eggs up to 150 are deposited in long chains on the host plants. The caterpillars are orange-reddish with dark head, prothoracic shield, and dorsal abdominal

bands. They are gregarious, burrow throughout the plants, and pupate in cocoons among the litter on the plants or ground. There are usually but two generations a year.

(14) Superfamily ZYGÆNOIDEA Gravenhorst 1843

KEY TO IMPORTANT FAMILIES

1. Proboscis obsolete or absent 2
 Proboscis well developed; antennæ filiform; labial palpi short; wings translucent; hind wings with Sc and R fused towards outer end of cell; base of R fused with Sc or obsolete; tibial spurs short. Larvæ with tufted hair. Small, often brightly colored or metallic moths. (Foresters, Burnet Moths.) ZYGÆNIDÆ
2. Females apterous; fore wings of males with A₁ and A₂ connected by a cross vein or fusing before the tip 3
 Both sexes winged; fore wings with A₁ and A₂ not connected or fusing apically 4
3. Larvæ construct bags or cases which are carried about and in which the moth may subsequently remain. (Bagworm Moths.) PSYCHIDÆ p. 470
 Larvæ not bag or case makers and adults free-living HETEROGYNIDÆ
4. Hind wings with Sc and R fused most of the length of the cell; wings thickly and loosely clothed with scales and curly hairs. Larvæ may be clothed with urticating setæ. Medium to large stout moths. (Flannel Moths.) MEGALOPYGIDÆ
 Hind wings with Sc and R uniting for a short distance at the base of the cell; wings thickly and loosely scaled. Larvæ with sucking disks replacing the prolegs; naked or with urticating hairs. Adults medium-sized, with stout hairy bodies. (Slug Caterpillar Moths, Cup Moths.) EUCLEIDÆ

Family EUCLEIDÆ¹ Comstock 1895 (Eu-cle'i-dæ, from the Greek *εὐκλεια*, glory, fame; in reference to the beautiful colors). Slug Moths, Cup Moths.

Medium-sized, short, robust, hairy moths of yellow, tawny, and brownish hues, some marked with green, reddish, and darker colors. Proboscis and maxillary palpi absent. Labial palpi short or rarely long. Tibial spurs usually short or in a few instances long. Wings rather short and broad, scaly and hairy. Fore pair with two internal veins; 1b forked at base; hind pair with three internal veins, 8 joined to base of cell. Larvæ short, fleshy, slug-like; head small and retractile; legs small or vestigial; prolegs absent; with thick cuticle or bearing tubercles and stinging and sometimes poisonous hairs; with cryptic colors. Pupæ enclosed in oval or round, hard, smooth silken cocoons opened by an operculum-like cap. The moths are nocturnal and not usually very abundant. The caterpillars are plant feeders.

The family is a small one of some 850 species, mostly tropical, but occurring

¹ Other names used are COCHLIDIIDÆ Hübner 1822, LIMACODIDÆ Walker 1855 and HETEROGENEIDÆ Meyrick 1895.

also in moist subtropical and temperate regions. The most important genera are *Euclea* Hübner, *Miresa* Walker, *Natada* Walker, *Parasa* Moore, *Sibine* Herrich-Schæffer, and *Thosea* Walker. The commonest North American species is the saddle back, *Sibine stimulea* Clemens, the stinging larvæ of which are green or with a green and brown saddle-like marking on the back. It feeds on cherry and oak, occurs in southeastern United States.

The white flannel moth, *Lagoa crispata* Packard, is a woolly, yellowish moth marked with brown broken bands on the fore wings. The densely hairy caterpillars feed on flowering blackberry along the Atlantic coast. It belongs to the related family MEGALOPYGIDÆ Berg 1882.

Family PSYCHIDÆ Boisduval 1829 (Psy'chi-dæ, from the Greek ψυχή, a spirit, a butterfly). Bagmoths, Casemoths, Bagworms, Basketworms.

Small to medium-sized cryptic-colored, hairy moths, all the males normally winged and swift fliers while the females are often highly specialized, larvi-

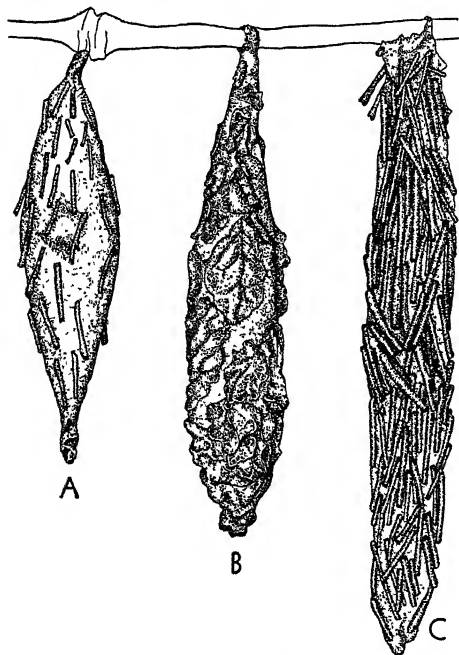


FIG. 150. Cocoons or bags of bagworms. A, *Thyridopteryx ephemeraformis* Haworth; B, *Oiketicus toumeyi* Jones; C, *O. townsendi* Cockerell.

form, and either apterous or with greatly reduced wings, legged or apodous, and living concealed in a bag or case. Head with loose hair. Antennæ moderately long to very short, often widely pectinate in the males. Eyes small and frequently hidden. Ocelli absent. Mouth parts rudimentary; proboscis absent; palpi absent or reduced to hairy tubercles. Legs short and may or may not be hairy; hind tibiae without middle spurs, and apical spurs short or absent. Wings scaled or nearly scaleless and transparent; hind pair of males with Sc separated from cell. Abdomen with terminal brushy tuft in females. Eggs thin and scale-like, mixed with hairs from the body. Caterpillars large; with scattered hairs and setæ; thoracic legs strong; prolegs reduced to crochets; living in cases of various shapes formed

of silk into which are incorporated leaves, twigs, earth, and other debris in more or less definite order or pattern; in extreme cases those of the females may attain a length of 4-5 in., male cases smaller. Those of *Psyche helix* Sieberling of Central Asia are commonly mistaken for snail shells. The larvæ

carry these cases by extending the head and thorax through the open basal end. They feed upon flowers, foliage, and bark. The moths are confined to forested areas. Pupation occurs in the attached and closed cases in which the females may remain until fertilized and in which they lay their eggs.

The family is a comparatively large one and, while extremely interesting and specialized, is not particularly important economically. Members occur throughout the tropics and temperate regions. Parthenogenesis is believed to occur in certain species where males have not been found. The important genera are *Acanthopsyche* Heylaerts (Ethiopian): the wattle bagworm, *A. junodi* Helyaerts on black acacia, South Africa, constructs a spindle-shaped bag 47–53 mm. long and 17–18 mm. in diameter. The apterous females remain in the bags and lay as many as 3,000 eggs each; *Amieta* Helyaerts (Australasia); *Eurukuttarus* Hampson (*Eurycyttarus*) (Nearctic); *Fumea* Stephens (Palæarctic); *Oiketicus* Guiding (Nearctic, Neotropical, Ethiopian); *Oreopsyche* Spuler; *Psyche* Schrank; *Rebelia* Helyaerts and *Scioptera* Rambur (Palæarctic); and *Thyridopteryx* Stephens (Nearctic): *T. ephemeraeformis* Haworth, transparent, smoky wings; 25 mm. long. The caterpillars feed on many kinds of trees and shrubs and construct bags up to 50 mm. in length in which the eggs are deposited and protected during the winter. It is the commonest member of the family in eastern North America.

(15) Superfamily NOCTUOIDEA Mosher 1916

KEY TO IMPORTANT FAMILIES

1. Subcosta apparently absent, fused with the radius except at the extreme base; proboscis well developed. Small, brightly colored, day-flying moths, frequently with hyaline wing spots, and of feeble flight. Many mimic bees and wasps. Hairy larvæ pupate in cocoon of silk and hair, usually on surface of ground **EUCHROMIIDÆ**
- Subcosta and radius separating before end of cell 2
2. Antennæ swollen or enlarged toward the tip; frenulum present. Small or medium-sized brightly colored spotted day-flying moths. The larvæ have few long hairs and lateral tufts and pupate in or on the soil without a cocoon. (Wood Moths.) **AGARISTIDÆ** p. 477
- Antennæ regularly tapering toward apex 3
3. Ocelli present, on vertex close to eyes 4
- Ocelli absent 9
4. Fusion of subcosta and radius of hind wing extending to or beyond middle of cell; antennæ of male pectinate; frenulum present. Small to medium-sized robust, nocturnal moths of variable and often bright colors. Hairy larvæ pupate in cocoon of silk and hairs. A large and injurious family. (Arctiids, Webworms, Tiger Moths, etc.)
ARCTIIDÆ (part) p. 472
- Fusion of subcosta and radius not exceeding the basal fifth of the cell 5
5. Fusion of subcosta and radius exceeding the basal fifth of the cell 6

palpi short and porrect or long and upturned; eyes smooth or rarely hairy. Ocelli present. Antennæ ciliate or pectinate. Tibial spurs well developed, the middle and hind tibiae sometimes spined. Wings well developed, fore wings smoothly scaled, areole present or absent, hind wings with two anal veins, and with frenulum and the retinaculum of the male usually elongated. The eggs may be pale, globular, or somewhat flattened, sculptured and laid in large masses on the host plants. The caterpillars are large, tuberculate, and covered with dense tufted hairs frequently reddish-brown and black. The prolegs have two incomplete circlets of hooklets. The caterpillars curl into a compact mass when disturbed and are called woolly bears or hedgehog caterpillars. In some species the full-grown larvæ hibernate. Cocoons are spun of silk into which are incorporated the shedding body hairs. The adults are largely nocturnal but are frequently found resting on plants during the day.

Among the many important and interesting genera and species are *Arctia* Schrank: the great tiger moth, *A. caja* (Linn.), is a remarkable north circum-



FIG. 151. The acraea moth, *Estigmene acraea* (Drury), a common North American species. (From *Insects of Western North America*.)

polar species which has no less than six color phases in the higher mountains and northern parts of North America.

Apantesis Walker; a group of striking-colored moths usually dark with linear white, yellow, or red patterns on the fore wings and black-margined and spotted yellow, orange, or red hind wings. The commonest North American species is *A. virgo* (Linn.), the larvæ of which feed upon many succulent weeds and truck crops.

Diacrisia Hübner (*Spilosoma* Stephens): the commonest European species is *D. vulpinaria* (Linn.) and of North America the Virginia tiger moth, *D. virginica* (Fab.). The caterpillars are omnivorous on a wide variety of plants.

Estigmene Hübner includes the well-known salt marsh caterpillar, *E. acraea* (Drury), of North America, which is a pest of many agricultural crops.

Halisidota Hübner includes the three important North American species, the silver-spotted halisidota, *H. argentata* Packard, which feeds on conifers; the hickory tiger moth, *H. caryæ* (Harris), on hickory and other hardwood forest trees; and the spotted halisidota, *H. maculata* (Harris), on a large number of deciduous trees and shrubs.

Hyphantria Harris, the so-called fall webworms, derive the common names from the large colonies of gregarious caterpillars that envelop whole limbs in webs within which they feed. These webs are most evident in summer and fall and are not to be confused with the more compact webs or tents of the tent caterpillars which appear in the early spring. The two most important North American species are the beautiful white moths designated as the **spotless fall webworm**, *H. textor* Harris, and the **fall webworm**, *H. cunea* (Drury). The long-haired caterpillars are forest and orchard inhabitants that feed upon broad-leaved deciduous trees and shrubs.

Isia Walker embraces the well-known **Isabella tiger moth** or **banded woolly bear**, *I. isabella* (Abbot and Smith), a dull orange-yellow, black-spotted moth, the densely hairy larvæ of which feed upon weeds, grasses, and cultivated crops.

Family PLUSIIDÆ Guenée 1842, 1852 (Plu-si'i-dæ, from the Greek *πλούσιος*, rich; referring to the metallic markings on the wings of certain species?). Semiloopers, Deltoid Moths, Underwings.

A fairly large family of moths separated from the NOCTUIDÆ which they resemble in form, color, and habits. The adults are characterized by ciliate or hairy eyes and the well-developed M_2 vein of the hind wings. Many of the larvæ are called semiloopers because of the looping method of crawling that results from the presence of only three pairs of posterior prolegs.

The most important economic genus is *Plusia* Ochsenheimer (*Autographa* Hübner). These moths are gray-mottled and have a characteristic white or silvery *gamma* or "Y" on each of the fore wings. The silver Y moth of the Old World is *P. chalcites* Esper which has become widely distributed and is known in Australia, New Zealand, and Hawaii. The silver Y moth of Australia is *P. argenifera* Guenée. The commonest Holarctic species is the **cabbage looper**, *P. brassicæ* (Linn.), whilst *P. gamma* (Linn.) is abundant in Europe. Simple specific names are illustrated by the two American species, *P. oo* (Cramer) on cotton in the southern states and *P. ou* Guenée on mint and other plants in the eastern states. *P. festucae* (Linn.) is common on grasses in the Palæarctic region and also infests rice in the Orient.

The **fruit-piercing moths** belonging to the genera *Calpe* Treitschke [*C. emarginata* (Fab.) and *C. excavata* Butler of eastern Asia], *Oithreis* [*O. fullonica* (Linn.) of eastern Asia and Austro-Malaysia], and *Ophideres* Bdv. (*O. tyrannus* Guenée of eastern Asia and Austro-Malaysia) have the ability to pierce citrus, tropical, and deciduous fruits and feed on the juices, thus causing great losses. The beautiful underwings belonging to the genus *Calocala* Schrank are a large group of forest-inhabiting species in which the fore wings are cryptic and the hind wings brightly colored. The caterpillars are frequently green to match the

foliage upon which they feed. The predacious *Eublemma amabilis* Moore feeds upon the lac insect, *Laccifer lacca* (Kerr), in India and is a pest of considerable importance to the lac industry.

Family NOCTUIDÆ¹ Stephens 1829 (Noc-tu'i-dæ, from the Latin *noctua*, a night owl; in reference to the crepuscular and nocturnal habits of the larvæ and adults). German, Eulen. French, Noctuidés. Millers, Noctuids.

Medium-sized to large; mostly somber, cryptic, or modestly colored, a few brilliant. Short and robust, scaly and hairy; crepuscular, nocturnal, and less often diurnal moths. Head small. Eyes large, smooth or hairy. Two ocelli present except in rare cases. Proboscis well developed or rarely absent. Maxillæ long and stout in most species. Maxillary palpi absent. Labial palpi variable; normal to long and prominent; ascending or porrect. Antennæ long, usually simple, hairy, serrate or sometimes pectinate in the males. Thorax large; dorsal scales often in tufts. Legs well formed; tibiæ spurred and with or without spines. Wings strong and with closely appressed scales forming intricate and beautiful patterns. Frenulum present. Fore wings with areole; Sc free at base and shortly fusing with R; M₂ may be reduced or absent. Hind wings usually paler than fore pair and, in certain species of so-called underwing moths, brightly colored, generally in shades of yellow, orange, buff, pink, and red; usually wider than fore wings; 1C absent; Sc and R converging to a point. Abdomen usually tapering anteriorly; hairy; and frequently with apical tufts.

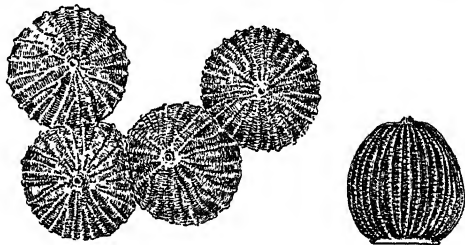


FIG. 152. Eggs of the corn earworm, *Heliothis armigera* (Hübner).

The eggs are normally globular or somewhat flattened with dorsal operculum and often radiating striæ; pale, dull, or green; laid in scattered clusters or in great masses by hundreds or even thousands on the host plants or in the habitat of the larvæ.

The larvæ, commonly known as armyworms and cutworms, are usually cylindrical and naked but a few are pubescent or hairy (*Acronicta*); dull, cryptic, or variously marked and striped and some striking in appearance; head large; prothoracic prespiracular tubercle with two setæ; mesothoracic tubercle VII with a single seta; thoracic legs well developed; normally five pairs of prolegs and usually a pair on segment VI; crochets in two rows. The habits are variable, but as a group they are herbivorous, and a great many species are notorious pests of agricultural crops. Feeding is largely at night

¹ Members of this and other related families have been variously known as NOCTUÆ Linnæus 1758; NOCTURNI Latreille 1802, NOCTUÆLITÆ Latr. 1809, NOCTUIDES, EREBIDA, NOCTUIDA Leach 1815, NOCTUADÆ Leach 1819, NOCTUÆ Hübner 1822; NOCTUIDÆ Stephens 1829; NOCTURNA Newman 1834; NOCTUIDÆ Hampson 1894, Rebel 1901, Spuler 1908.

but when numerous the caterpillars often march and spread destruction during the day as well.

Such forms as the cosmopolitan armyworm, *Leucania*¹ *unipuncta* (Haworth) (*Cirphis*), and the New Zealand armyworm, *Persectania ewingi* Westwood, are very injurious to cereals and grasses, but these and other species are also omnivorous. The variegated cutworm, *Lycophotia margaritosa* (Haworth), and the greasy cutworm, *Euxoa*² *ypsilon* (Rottemburg), are both widely distributed and general feeders. The mealie stalk borer, *Busseola fusca* Hampson, seriously damages maize stalks in Africa while the corn earworm, *Heliothis armigera* (Hübner) [*Chloridea obsoleta* (Fab.)], is a cosmopolitan pest of corn that is very destructive to the kernels just before they ripen. The latter is also a major pest of cotton and tomatoes in many localities. Members of the European

genera, *Bryophila* Treitschke and *Parascotia* Hübner, feed on lichens and algae and the latter also on fungi.

Many genera feed on the seeds of a great variety of plants. Others are stem borers while the great majority are foliage feeders.

The life histories of most forms are quite simple but in certain cases considerable complexity is involved. The eggs may be laid in the late summer or fall and may remain over winter or they may hatch immediately and the young caterpillars hibernate. In many cases,



FIG. 153. Caterpillars of the variegated cutworm, *Lycophotia margaritosa* (Haworth). (From *Insects of Western North America*.)

however, the eggs are laid in the spring, early summer, and midsummer. There is usually a single generation in the cooler regions and two or more in the warmer. In size the adults have an average wing expanse from 40–50 mm., which varies from the small bright tropical American *Spragueia dama* Guenée with an expanse of but 15 mm. to the large black witch, *Erebus odora* (Linn.), expanse 110–160 mm., which breeds in tropical America and regularly migrates as far north as Canada and northern California. The huge gray *Thysania zenobia* Cramer, also of tropical America, is as large as the latter and also abundant in Mexico and ranges into southern United States.

This large family of moths comprises some 500 genera and 20,000 species and ranges throughout the entire world, being especially abundant in forested

¹ The genus *Leucania* was erected by Hübner in 1816 and *Cirphis* by Walker in 1865.

² *Euxoa* Hübner 1816 has precedence over *Agrotis* Hübner 1806, the latter being a Tentamen genus.

and plains areas and reaching its maximum development in North and South America. The caterpillars often appear in countless numbers and march in great armies; hence the name armyworms. The common cosmopolitan armyworm, *Leucania unipuncta* (Haworth), the widespread greasy cutworm, *Euxoa ypsilon* (Rottemburg), the variegated cutworm, *Lycophotia margaritosa* (Haworth), and the Australian Bugong, *Euxoa infusca* (Boisduval), are four such species. The caterpillars of the last are eaten by the Bushmen, and the adults may be encountered at sea (Tillyard, 1926).

The cosmopolitan genera include *Heliothis* Ochsenheimer (*Chloridea* Duncan), *Hadena* Schrank, and *Leucania* Hübner (*Cirphis* Walker). The remarkable whistling moth, *Hectasia fenestrata* Boisduval, and two related species of Australia have a large crescent-shaped ribbed membranous area on each fore wing which produces a whistling sound in flight. Though formerly placed in the NOCTUIDÆ, they are now grouped in the family AGARISTIDÆ.

Family NOTODONTIDÆ Stephens 1829 (No'to-don'ti-dæ, from the Greek *νότον*, back, + *ὀδους*, *ὀδοντος*, tooth; in reference to the tufts on the wings and the tooth-like prominences on the backs of the caterpillars). Prominents, Puss Moths.

Medium-sized to large, somber-colored gray or brown moths which are nocturnal and somewhat resemble the noctuids. The wings and bodies are well clothed with scales and hairs. Proboscis present and distinct, vestigial, or absent. Antennæ usually simple, or pectinate in the males. Maxillary palpi absent. Hind femora with long hairs; tarsi no longer than the tibiae. Wings fully scaled; some with backward-projecting tufts on the hind margins which protrude when the wings are folded. These, with the large tubercles and processes on the backs of the larvæ, are responsible for the scientific name. Cu vein trifold and areoles often present in the fore wings; hind wings with veins 7 and 8 uniting near the middle of the cell; 5 is vestigial, 1C absent, Sc and R separate. The abdomen is quite hairy and is with or without an anal tuft. Eggs rounded, pale, laid singly or in small or large masses on the host plants. The larvæ cylindrical; naked or tuberculate and hairy; labial notch deep and acute; four median prolegs usually present, the anal pair being vestigial, modified, or absent; true legs rarely greatly lengthened and held forwards in repose; body with dorsal humps, tubercles, tentacles, and spines giving a grotesque appearance; often brightly colored and striped; gregarious; some are attacked only by the median prolegs



FIG. 154. Adult of the armyworm, *Cirphis unipuncta* (Haworth). (From *Insects of Western North America*.)

with the anterior and posterior ends raised into the air. Pupæ naked and enclosed in a cell in the ground or in a loose cocoon in debris.

One of the most unusual caterpillars is called the lobster, *Stauropus fagi* (Linn.), of Europe, Asia, and Indo-Malaysia, whose very long true legs are held forwards like the claws of a lobster. The larvæ feed on the foliage of deciduous trees. A similar species, *S. alternus* Walker, has slender larvæ with the head and posterior end of the abdomen greatly enlarged; the true legs, especially the second and third pairs, are much lengthened and the anal prolegs are missing. They feed on acacia in India. The puss moths, belonging to the genus *Cerura* Schrank, are Holarctic and Indo-Australian. The caterpillars are bulky anteriorly and pointed posteriorly and have a pair of long anal eversible tubes. *C. vinula* (Linn.), the common species in Europe, feeds on poplars and willows.

The most important North American species is the red-humped caterpillar, *Schizura concinna* (Abbot and Smith), the full-grown larvæ being 25–35 mm. long, yellow or red, with six or eight black tubercles on each segment, the entire body lined with white, brown, red, and black. The head is bright red as is also the fourth segment which has a prominent dorsal hump and two conspicuous black tubercles. Pupation occurs in the soil, where hibernation also takes place. The adults are reddish-brown and gray and have an expanse of 30–35 mm. This species usually has two generations a year. The caterpillars are gregarious and are general feeders on deciduous trees and shrubs and are pests in orchards, being particularly fond of prune and walnut trees. The species is widely distributed throughout the temperate parts of the continent. Another economic species is the yellow-necked caterpillar, *Datana ministra* (Drury), the larvæ of which are black with yellow longitudinal stripes and long soft white hairs. The head and prothoracic shield are yellow or orange. Its food habits and distribution are very much like those of the preceding species.

Family LYMANTRIIDÆ Hampson 1892 (Ly'man-tri'i-dæ, from the Greek *λυμαντήρ*, a destroyer, despoiler; because of the destructiveness of the caterpillars). Tussock Moths.

Medium-sized, robust, hairy and scaly moths, 10–36 mm. long, which are mostly nocturnal with certain species partly diurnal and crepuscular. While the males are winged, the females of a number of genera (*Hemerocampa*, *Acyphas*, and *Orygia*) have only rudimentary wings and are flightless. Antennæ mostly pectinate or plumose apically and specially developed in the males. Proboscis rudimentary or absent; palpi short. Ocelli absent. Legs densely haired. Wings well developed or atrophied; frenulum present in most genera. Abdomen of the females has anal tufts used in covering the eggs and two brightly colored dorsal glands. Spiracles with hoods dorsad. Eggs often laid in masses and covered with cement and body hairs; frequently deposited on the pupal case; and are the hibernating stage in certain temperate species (*Hemerocampa*, *Orygia*). Caterpillars large, cylindrical, and densely covered with long hairs

and some also with tufts or brushes, hairs often stinging or urticating; some are gregarious and live in closely woven and even bag-like webs, especially as immature hibernating forms (*Euproctis*). Such nests are often noted on ornamental trees and shrubs wherever these insects occur. Pupation takes place in tough, felt-like cocoons into which are incorporated hairs from the bodies of the larvæ.

This is a rather small but very important destructive family of moths that primarily infest forested areas and are particularly destructive to broad-leaved deciduous trees in the temperate regions. The caterpillars may occur in such numbers as to completely overrun and defoliate large areas of parks and woodlands. The most important genera include the almost cosmopolitan *Lymantria* Hübner (*Liparis* Ochsenheimer, *Porthetria* Hbn., *Psilura* Stephens); the Holarctic *Orygia* Ochs. (*Notolophus* Germar); the European *Dasychira* Stephens, *Euproctis* Hbn., (*Nygmia* Kirby), *Porthesia* Stephens, and *Silpnolia* Westwood; the North American *Hemerocampa* Dyar; and the Australian *Acyphas* Walker and *Iropoca* Turner (the latter may be confused with *Iropocus* Gloger 1842 in MAMMALIA).

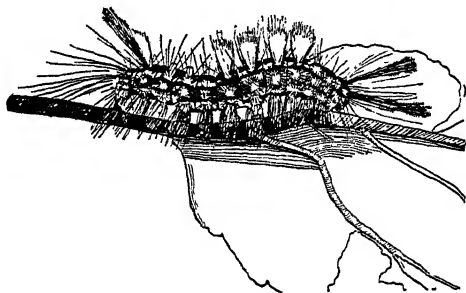


FIG. 155. Caterpillar of the California tussock moth, *Hemerocampa vetusta* (Boisduval). (From *Insects of Western North America*.)

The most important species is the notoriously destructive gypsy moth, *Lymantria dispar* (Linn.),¹ a Palearctic species which was unwittingly introduced into the United States and established at Medford, Mass., in 1869 and became very destructive in 1889 and thereafter, stripping the broad-leaved evergreen and deciduous ornamental and forest trees around Boston and rapidly spreading throughout New England. A similarly injurious related species, the brown-tail moth, *Euproctis chrysorrhæa* (Linn.),² was also introduced into the same state and discovered in 1897. It added materially to the destructiveness of the gypsy moth. The combined efforts of the state and federal governments in 1905 and subsequently only abated the depredations; and the millions spent in attempts to control and prevent the spread of these two moths have

¹ The generic designation of this species has long been an object of much confusion since no less than 19 distinct generic names have been ascribed to it. *Lymantria* was erected by Hübner in 1816 as was also *Porthetria*. The nun moth, *Bombyx monacha* Linn., was made the type of the former which forced the latter into synonymy. *Liparis* Ochs. 1810 is preoccupied by *Liparis* Scopoli 1777 in PISCES. *Onceria* Hübner is used for a different genus. The genus *Lymantria* as designated above is accepted by M. Hering (*Die Tierwelt Mitteleuropas*, p. 484, 1932) and by F. Byrk (*Lepidopterorum Catalogus*, pt. 62, pp. 144-145, 1939).

² At least 38 different generic names have been applied to this species at various times. The genus *Euproctis* was erected by Hübner in 1816 whereas *Nygmia*, used by some to replace the former, was not erected by Kirby until 1892. The above designation has been generally accepted both in Europe and America.

confined it to New England and have greatly reduced their destructiveness, especially through the introduction of natural enemies. The minute hairy caterpillars may be carried by the winds. The more mature larvæ are thickly clothed with urticating hairs which cause a painful skin rash to humans known as urticaria.

The satin moth, *Stilpnotia salicis* (Linn.), is a beautiful white European species, the caterpillars of which seriously defoliate poplars and willows. It was introduced into North America and also first observed at Medford, Mass., in 1920. It has since been found in British Columbia, Washington, and Oregon. The white-marked tussock moth, *Hemerocampa leucostigma* Smith and Abbot, in which the females have only vestigial wings, is the commonest representative of this genus throughout the forested areas of North America.

The Mexican silk moth, *Eutachyptera psidii* (Sallé), spins nests of silk which have been carded and spun by the natives of Oaxaca, Mexico. The species ranges from southern Arizona south into Guatemala and the caterpillars feed on guavas (*Psidium*) and oaks.

(16) Superfamily DREPANOIDEA Forbes 1923

KEY TO IMPORTANT FAMILIES

1. Tympanum well developed; chaetosema or head bristles vestigial or absent; dip in Sc of hind wings beyond discal cell, and sometimes connecting with R₄ 2
 Tympanum not developed; chaetosema present; dip in Sc of hind wings opposite the middle of discal cell; hind wings fringed. Day-flying, Indo-Malaysian moths **CALLIDULIDÆ**
2. Ocelli vestigial; subcosta and radius of hind wings strong and parallel to beyond the end of the cell, then approaching very close or fusing for a short distance; proboscis aborted. Small or medium-sized, dull-colored, slender, nocturnal moths with large wings, the fore pair of which are pointed and curved downwards. Caterpillars destitute of hairs and without anal prolegs. Pupation occurs in a silken cocoon. (Hooktips.) **DREPANIDÆ**
 Ocelli well developed; antennæ laminated; proboscis weak; frenulum well developed and knobbed in male. Hairy moths. Palearctic. (Thyatirids.) **THYATIRIDÆ** p. 486

(17) Superfamily URANIOIDEA Forbes 1923

KEY TO IMPORTANT FAMILIES

1. Frenulum absent; hind wings with basal costal area greatly expanded and usually with a pointed angle or tail. Large, slender-bodied, diurnal, tropical moths **URANIIDÆ**
2. Frenulum rudimentary; Sc of hind wings sharply divergent from R from near the base; R₄ and R₅ stalked, widely separated from R₃. Medium-

sized, robust hairy diurnal moths with wings often notched or concave behind; with normal resting position MIMALLONIDÆ

3. Frenulum well developed. Small and delicate tropical moths with large wings EPIPLEMIDÆ

(18) Superfamily SPHINGOIDEA Dyar 1902

Family SPHINGIDÆ Leach 1819 (Sphin'gi-dæ, from the Greek σφινξ, the Sphinx in mythology; referring to the grotesque appearance of the caterpillars in repose). German, Schwärmer. French, Sphingidés. Sphinx Moths, Hawkmoths, Hummingbird Moths, Sphingids.

Mostly large, beautiful, robust, diurnal, crepuscular and nocturnal, active and powerful flying moths with hairy bodies also clothed with closely appressed

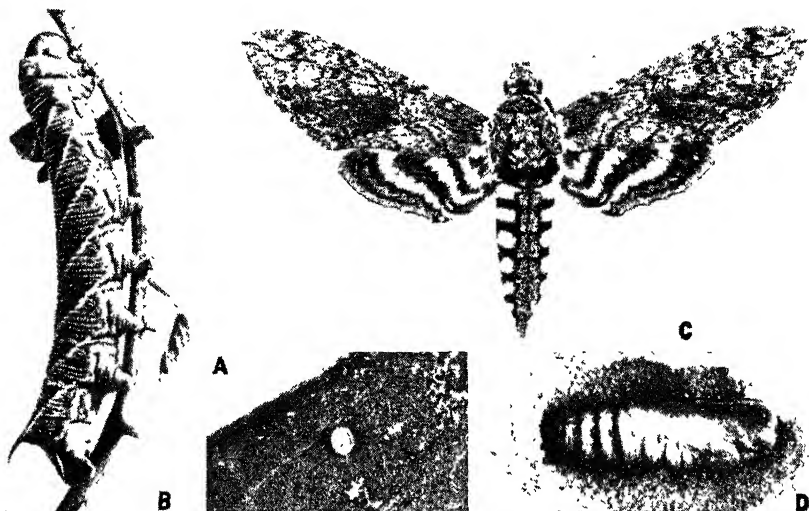


FIG. 156. Tomato sphinx moth, *Protoparce quinquemaculata* (Haworth). A, egg (by Wyomere); B, caterpillar (after Folsom); C, adult moth (by Michelbacher); D, chrysalis (by Michelbacher).

scales arranged in remarkable color patterns. Head large. Eyes prominent, naked. Antennæ usually thickened apically and pointed and hooked at the tip; ciliate or pectinate in the males. Proboscis often extremely long, up to 250 mm. in the tropical American genus *Cocytius* Hübner; tuberculate in the oriental and African *Polyptychus* Hübner; reduced or obsolete in certain others of the AMBULICINÆ. Palpi present. Wings large, narrow, and frequently pointed, with oblique and rarely scalloped margins; fore pair much the larger, often cryptically colored whereas the hind pair may be brilliant; heavily scaled or partly or entirely naked and transparent; frenulum well developed; subcosta

and radius connected by a strong cross vein at or just before the middle of the cell, then parallel to the end of the cell; folded flat over the body in repose. Abdomen robust and pointed or spindle-shaped; some species with expansile tufts of hair at the anal end.

The larvæ or hornworms are large, robust, cylindrical, smooth, granulate, tuberculate, and rarely with fine hairs; anterior segments retractile; abdominal segments each with six to eight annulets; prolegs normal; posterior horn on abdominal segment VIII is usually present in first instar and may be retained throughout the larval stage or may be shed and replaced by a scar or tubercle; longitudinal and lateral oblique body stripes and conspicuous markings around the spiracles may be present. Some larvæ assume grotesque attitudes which are thought to be responsible for the common name "sphinx moths" of the members of the family. They are wholly phytophagous and are usually solitary but may at times occur in large numbers and do great damage to plant life. Pupation occurs in thin cocoons in the litter on the ground or in subterranean earthen cells. The pupæ are normally smooth, shining, reddish-brown, cylindrical, and pointed posteriorly; the proboscis may be encased with the body or in a separate pitcher-handle-like sheath. Hibernation frequently occurs in the pupal condition, especially in the temperate regions.

The adults are well-known conspicuous moths which are among the swiftest flying insects. They are capable of long sustained flights and certain widely distributed species, like the oleander hawkmoth, *Daphnis nerii* (Linn.), the white-lined sphinx, *Deilephila lineata* (Fab.), the death's head moth, *Acherontia atropos* (Linn.), the morning glory sphinx moth, *Herse convolvuli* (Linn.), and the pink-spotted hawkmoth, *Herse cingulata* (Fab.), migrate long distances. Some of them have been taken hundreds of miles at sea. The moths fly mostly at dusk and dawn, but those of the genera *Cephonodes* Hübner, Ethiopian, Oriental, and Australian, and *Hæmorrhagia* Grote and Robinson, North and South American, are diurnal, while the death's head moth, *Acherontia atropos* (Linn.), and some others are more strictly nocturnal.

The adults sip nectar from various flowers and are partial to those with deep corollas. They do considerable good in cross-pollinating many economic plants. In size the adults vary from the small *Euproserpinus phaelon* Grote and Robinson of California, which has an expanse of 32 mm., to the large Australian *Cizara australasiæ* Donovan, which may attain a wing expanse of 215 mm. The larva of the latter feeds upon *Protea* and *Eucalyptus* and, because of the enlarged posterior end, is called the two-headed caterpillar.

In the tropical regions two generations a year are produced as a rule whereas in the temperate areas there is but one generation.

The family is widely distributed throughout the world and embraces some 175 genera and 900 species.

The most important genera and species are given in systematic sequence. *Herse* Oken, five species (Holarctic, Ethiopian, Australasian): the morning glory sphinx, *H. convolvuli* (Linn.) is a very common tropical and southern European species, and the pink-spotted hawkmoth, *H. cingulata* (Fab.)

(Holarctic, Neotropical, and Oceanic), both feed on members of the CONVULVACEÆ.

Acherontia Laspeyres, three species, includes the famous death's head moth, *A. atropos* (Linn.), a large black species with various shades of brown and yellow with dorsal thoracic markings resembling a human skull. The adults are nocturnal and make a distinct squawking noise by forcing air across an aperture in the antlia or spiral proboscis. The adults have long been feared by the peasants of Europe as an omen of ill luck. The moths in early days won much notoriety as robbers of beehives, but they can easily and effectively be excluded from the hives by a suitable entrance. The huge green, yellow, and gray caterpillar may measure up to 100 mm. in length. The death's head moth is able to make a noise by rasping its mouth parts (Schnack). The larvæ feed chiefly on various solanums but are also somewhat of general feeders. The distribution is Ethiopian and Palæarctic.

Protoparce Burmeister, 35 species (Nearctic and Neotropical): the tomato worm, *P. quinquemaculata* (Haworth), and the tobacco worm, *P. sexta* (Johanssen), are the most important economic representatives and are pests of solanaceous plants in much of North and South America. The former has been introduced into northern Europe and Hawaii. *Sphinx* Linn., 31 species (Holarctic and Neotropical): the privet hawkmoth, *S. ligustri* (Linn.), is one of the commonest species in Europe and northern Asia. The larvæ feed on privets and various other members of the OLEACEÆ.

Other species which should be mentioned are the willow hawkmoths, *Smerinthus ocellata* (Linn.), of Europe and northern Asia and *S. cerisyi* (Kirby) of North America; the poplar hawkmoths, *S. populi* (Linn.), of Europe and northern Asia and *Pachysphinx modesta* Harris of North America; the grape hawkmoths, *Pholus achemon* Drury of North America and *P. vitis* (Linn.) of tropical North and South America. The white-lined sphinx, *Deilephila*¹ *lineata* (Fab.) (*Deilephila* Ochsenh.), cosmopolitan and the most widely distributed species in the family, is often abundant and injurious to a large variety of plants. The adults often fly during the day. The spurge hawkmoth, *D. euphorbiæ* (Linn.), and the sea buckthorn hawkmoth, *D. hippophææ* (Esper), of Europe and the Caucasus, and the madder hawkmoth, *D. galli* (Rottenberg), are all Palæarctic. The oleander hawkmoth, *Daphnis nerii* (Linn.), is Ethiopian, Palæarctic, and Oriental.

(19) Superfamily GEOMETROIDEA Forbes 1923

KEY TO IMPORTANT FAMILIES

1. Fore wings with areole usually present 2
Fore wings with areole absent 4
2. Hind wings with Sc + R₁ and R₅ coalesced for a short distance near the beginning of the half of the discal cell, thence rapidly diverging; fore wings with R₁ often fusing with areole and never fusing with Sc.

¹ The genus *Deilephila* was erected by Laspeyres in 1809 whereas the genus *Celerio* was not established until 1815 by Oken. Therefore the former has priority.

Small whitish, gray, or brown moths with delicate wavy marking on wings. Widely distributed. (Wave Moths.) . . . **ACIDALIIDÆ** p. 486

Hind wings with $Sc + R_1$ and R_3 coalesced to or beyond the middle of discal cell, or with a short union near end of cell . . . 3

3. Fore wings with one or two accessory cells, R_1 often fusing or coinciding with areole at base and rarely uniting with Sc . Adults small usually pale-colored moths. Widespread. (Carpet Moths, Pug Moths.)

LARENTIIDÆ

Fore wings without accessory cells, R_1 often fusing with areole or with Sc ; hind wings with M_2 well developed from beyond middle of cell. Larvæ are the well-known cankerworms. Adults small to medium, delicate, somber or brightly colored moths, some females with vestigial wings. Widespread. (Cankerworms.) . . . **ENOCHROMATIDÆ** p. 486

4. Hind wings with Sc approximated to cell usually to about the middle, M_2 weak or absent. Larvæ loopers, often resembling twigs. Australian

BOARMIIDÆ

Hind wings with Sc approximated to cell near base, diverging at or before the middle; M_2 developed and close to M_1 ; frenulum and retinaculum strongly developed, weak, or absent. Larvæ loopers, measuring worms. Adults small to medium, with bright or cryptic colors, some females with vestigial wings. Cosmopolitan. (Geometers, Emeralds.)

GEOMETRIDÆ



FIG. 157. Eggs of the fall cankerworm, *Alsephila pomataria* (Harris).

Family GEOMETRIDÆ Stephens 1829 (Ge'o-met'ri-dæ, from the Greek γεωμέτρης, geometer, a land measurer; referring to the looping gait of the caterpillars). German, Spanner. French, Géométridés. Geometers, Geometrids, Emeralds.

Small to medium-sized, slender, fragile, mostly cryptic-colored, crepuscular and nocturnal moths, some of which are attracted to lights. While most species are winged in both sexes, there are a number in which the females are either apterous or have rudimentary wings. The ocelli and maxillary palpi are

absent. Proboscis present or rarely absent. Legs slender; the tarsi often long, naked or slightly hairy. Wings without areole in fore pair and the frenulum and retinaculum well developed, reduced, or absent; vein 5 in fore wing nearer to 6 than to 4; 1C absent in hind wings. Abdomen with hood-like tympanum opening ventrally at base. Color-sex dimorphism common. Eggs variable, but mostly somewhat flattened. Larvæ variously called loopers, measuring worms, and spanworms because of their method of locomotion resulting from the absence of prolegs in the middle; only two to three pairs of prolegs at posterior

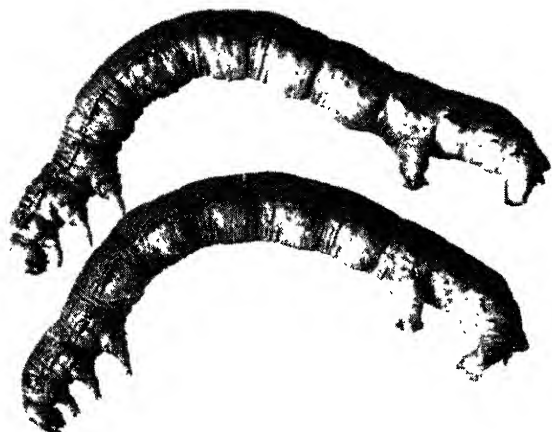


FIG. 158. Caterpillars or measuring worms of the omnivorous looper, *Sabulodes caberata* Guenée. (From *Insects of Western North America*.)

end, anal pair specially well developed; usually smooth, rarely with hairs; often rough and tuberculate; cryptic or dichromatic, in the latter case green and reddish or yellowish. They are frequently attached by the prolegs and assume rigid attitudes resembling dry twigs. Pupation may occur in a thin cocoon on the host, in litter, or in a cell in the ground.

This formerly very large family has recently been divided into a number of families,¹ and the classification is still somewhat uncertain. In these related groups there are upwards to 2,000 described species widely distributed throughout forested and plains areas of the world. The larvæ feed chiefly upon living plants, but a few are able to subsist upon dry vegetable matter.

The spring cankerworm, *Paleacrita vernata* (Peck), is the most important representative in North America. The striped green caterpillars feed upon

¹ These families include BREPHIDÆ Hübner 1826, ACIDALIIDÆ Guenée and BOARMIIDÆ Guenée 1844, HEMITHEIDÆ Braund 1845, CYMATOPHORIDÆ Herrich-Schäffer 1847, GENOCHROMATIDÆ Guenée 1857, LARENTIIDÆ Butler 1874, THYATIRIDÆ Grote 1890.

the fruit and foliage of wild and cultivated fruit trees and a variety of other plants. Pupation is in the ground, and wingless females emerge from the soil and oviposit in the spring of the year. The related **fall cankerworm**, *Alsophila pometaria* (Harris), (family **ÆNOCHROMATIDÆ**) is similar, but the females mature and oviposit in the fall, the eggs remaining on the host over winter and hatching in the following spring. The **gooseberry spanworm**, *Cymatophora ribearia* (Fitch), (family **THYATIRIDÆ**) is a common species in eastern North America. The European *Erannis defoliaria* (Clerck) (*Hybernia*) (family **BREPHIDÆ**) has wingless females and winged males. It is often very abundant and destructive to fruit and forest trees. The **herbarium moth**, *Eois ptelearia* Riley, (family **ACIDALIIDÆ**) is peculiar in that the larvæ are injurious to dried plant specimens in herbariums in the United States. The rough larvæ have two pairs of prolegs and spin open, lace-like cocoons.

Many other well-known species, too numerous to mention, occur in almost every region.

(20) Superfamily **BOMBYCOIDEA** Dyar 1902

KEY TO IMPORTANT FAMILIES

1. Cubitus of fore wings apparently three- or rarely two-branched . . . 2
 Cubitus of fore wings apparently four-branched 3
2. Frenulum present, about one sixteenth the length of the hind wings; proboscis aborted. Large dull-colored moths. Larvæ hairy and pupating in silken cocoons **THAUMETOPÆIDÆ**
 Frenulum absent or, if present, not exceeding the front basal angle of the wing; proboscis absent; antennæ bipectinate in both sexes. Medium-sized robust densely hairy or scaly moths. Larvæ smooth, with anal horn, and pupate in thick silken cocoons. (Silkmoth, Silkworm.) **BOMBYCIDÆ** p. 488
3. Second cubital vein of fore wings arising from the cell about one third out or from nearer the base; last radial vein stalked with the first medial; frenulum absent, the basal front angle of the hind wings expanded and furnished with a couple of short extra veins; proboscis absent; antennæ pectinate in both sexes. Medium-sized to large robust mostly brown or somber moths which are nocturnal. The caterpillars are hairy and armed with lateral tufts and pupate in a cocoon of silk and hair. Many species are serious pests. (Tent Caterpillars, etc.) **LASIOCAMPIDÆ**

Family LASIOCAMPIDÆ (Harris 1841), Waterhouse 1882 (La'si-o-cam'pi-dæ, from the Greek *λασιος*, hairy, shaggy, + *κάμπη*, a caterpillar, or a silkworm; referring to the hairy larvæ or to the extensive silken webs). German, Glucken. Tent Caterpillars, Eggars, Lappet Moths, Lackey Moths.

Medium-sized to large hairy and scaly, stout-bodied, nocturnal and diurnal swift-flying moths closely related to the silkworms, some of them producing silk used commercially. Antennæ bipectinate in both sexes. Eyes hairy. Ocelli greatly reduced or absent. Proboscis greatly atrophied. Maxillary palpi

vestigial or wanting. Labial palpi well developed and may be snout-like and porrect. Legs very hairy; tibial spurs short, those on the middle legs absent. Wings normal or very large, frenulum absent, sexual dimorphism pronounced in *Crexa* Walker and *Pinara* Walker of Australia. Fore pair with R_4 free and lengthened or arising from the stalked R_2 and R_3 ; R_5 and M short-stalked; M_2 arising from lower angle of cell; Cu_2 absent; areole absent. Hind pair with



FIG. 159. A gregarious colony of the forest tent caterpillar, *Malacosoma disstria* Hüber, resting on the limbs of an apple tree. (From *Insects of Western North America*.)

2A extending to outer angle. Eggs smooth, oval or rounded. Often deposited in bands around twigs and covered with a thick layer of cement, generally laid in summer and fall and hatch the following spring in the temperate regions, the tiny caterpillars hibernating in the eggshells. Caterpillars large, cylindrical, body setae hidden by long hairs; variously and often brightly colored; with six pairs of prolegs and the crochets biordinal and multi-serial. The larvæ normally feed upon the foliage and young fruit of broad-leaved evergreen and deciduous trees. Certain species like the tent caterpillars, *Malacosoma* spp., spin extensive webs which may envelop entire trees. Chrysalis smooth, without cremaster, and enclosed in a silken cocoon in debris or in sheltered places.

This is a comparatively large family consisting of 142 genera and 1,355 species widely distributed and especially well developed in the tropical regions of Asia, Africa, and South America. The members are largely restricted to forested areas. The most important genera are: *Cosmotriche* Hübner, 23 species

(Palæarctic and Australian); *Epicnaptera* Rambur, nine species (Holarctic); *Eriogaster* Germar, 12 species (Palæarctic); *Euglyphis* Hübner, the dominant genus, with 302 species (Nearctic and Neotropical); *Lasiocampa* Schrank, 24 species (Palæarctic): *L. quercus* (Linn.), the commonest European species, a pest of forest trees; *Malacosoma* Hübner, 26 species, widely distributed in all parts of the world excepting New Zealand.

The larvæ are commonly called tent caterpillars because of their extensive webs which may envelop the host plants. The moths are various shades of tan and reddish-brown and have paler and darker diagonal cross bars on the wings. The larvæ hatch soon after the eggs are deposited but remain within the shells until the first warm days in spring when they all issue at once and begin spinning their webs as the deciduous trees are budding, blooming, and leafing out. They are gregarious, usually occur in large colonies, and often do considerable damage by defoliating large areas of forest and fruit trees.

The lackey moth, *M. nuestrium* (Linn.), is the most important and destructive species in Europe while in North America the American tent caterpillar, *M. americana* (Fab.), in the east; the forest tent caterpillar, *M. disstria* Hübner, throughout most of the continent; and the Great Basin tent caterpillar, *M. fragilis* (Stretch) in the west, are the commonest destructive species. *Tolypha* Hübner with 90 species is Neotropical, and *Tragama* Moore, 66 species, is Ethiopian, Oriental, and Indo-Malaysian.

The oldest known and most valuable species is the Syrian silkworm, *Pachypasa otus* Drury, a large buff and dark-brown moth with a wing expanse of 150 mm. The larvæ feed chiefly on *Pistacia tentiscus* but have also been reared on holly oak, ash, cypress, and *Thuja*. This native wild silkworm was collected and reared for its silk by the Greeks and Romans from very early times until long after the introduction of the Chinese silkworm about 550 A.D. It is referred to by Aristotle as Bombykion, by Pliny as bombyx, bombylis, and necydaleus, and by Aldrovandus (1602) as Bombylio. The silk produced by the caterpillars is white and is spun into a large thick cocoon. It was produced only in small quantities because of the single generation and the fact that the larvæ hibernate and often perish during the winters. The silken goods known as *cos vestris* produced on the Island of Cos were worth their weight in Roman gold. The moth was introduced into the western Mediterranean region of Europe very early and was quite important in Italy from 1860 to 1875 but has been wholly supplanted by the Chinese silkworm.

The bibindandy, *Borocera madagascariensis* Boisduval, the most important silkworm of Madagascar, produces the silk used in making lambalandy. The hosts are many, including both wild and cultivated trees, and the caterpillars are considered pests of citrus, guavas, and peaches.

Family BOMBYCIDÆ Leach 1819 (Bom-byc'i-dæ, from the Greek βόμβυξ, a silkworm). Silkworms.

This small family includes the important Chinese silkworm, *Bombyx mori* Linn., which, with the possible exception of the honeybee, has since the begin-

ning of written history been the most commercially important beneficial member of the insect world. It is the basis of large industries not only in Asiatic and European countries, where the caterpillars are reared and the raw silk produced, but also in North America where much of the manufacturing of silk products occurs. Many vain efforts have been made to establish sericulture permanently in the United States¹ but the high cost of hand labor has been the limiting factor.

The Chinese silkworm is native to Asia and has been domesticated for so many years that it can no longer exist without the care of the human race. By careful selection many races have been developed to meet the various needs of

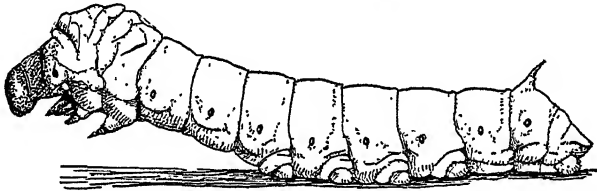


FIG. 160. Mature caterpillar of the Chinese or mulberry silkworm, *Bombyx mori* Linn. (U.S.D.A.)

climate, rapidity of reproduction, color, quantity, and quality of the silk to be produced.

The adult moths have a wing expanse of 40–45 mm., are robust and creamy white, with several faint lines across the fore wings. The small smooth sub-spherical eggs are first yellowish-white and become darker as the embryo develops; each female lays about 300. The caterpillars are rough and wrinkled, naked, whitish, attain a length of 45–55 mm., and have a short anal horn. They feed on white and black mulberry leaves which are picked for them each day but they will also eat the leaves of other mulberries, osage orange, and even lettuce. Maturity is reached in 45 days and pupation occurs in a thick oval white or yellow silken cocoon. The adults emerge in 12 to 16 days. There are races of from one to six broods a year. For commercial purposes the pupæ are killed in the cocoons by heat or hot water and the raw silk reeled for subsequent use.

The larvæ are subject to a severe hereditary disease known as pebrine which is caused by a myxosporidian parasite, *Nosema bombycis* Nägeli, and transmitted from the moths through the eggs. It is possible to eliminate this disease by a microscopic examination of the blood of the females and the use of eggs from those free from contagion. The caterpillars are also subject to parasitism by certain tachina flies which oviposit on the mulberry leaves and thus gain entrance to the body by means of the alimentary tract. Silkworms are readily reared in confinement by feeding the developing larvæ tender and fresh daily food. They remain in small uncovered containers and do not roam about if unconfined as do the caterpillars of all our common moths.

¹ ESSIG, E. O., "The Silkworm," in *History of Entomology*, Macmillan, N. Y., pp. 231–236, 1931.

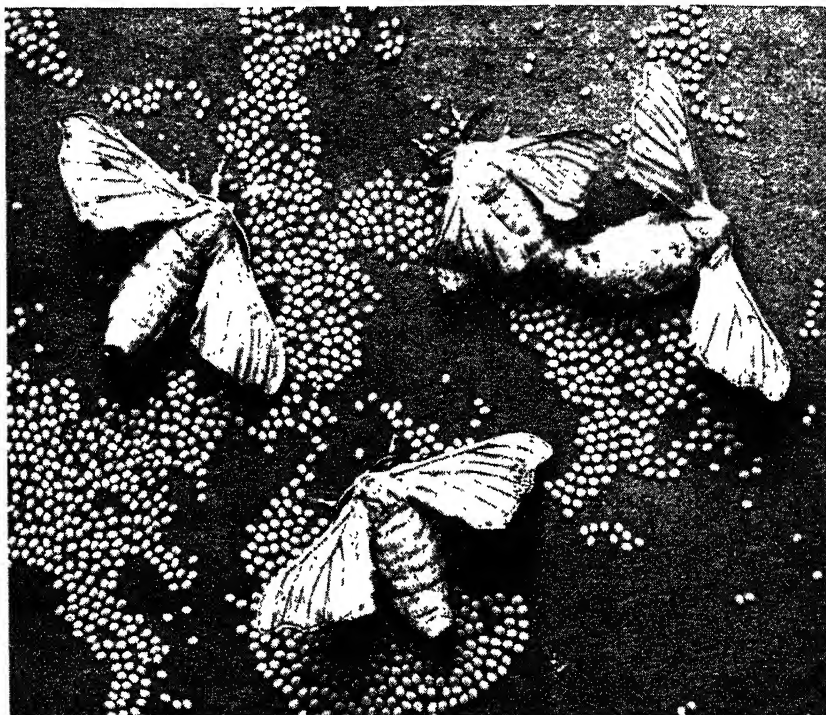


FIG. 161. Adult silkworm moths, *Bombyx mori* Linn., mating and laying eggs. The bodies of the females are much distended because of the great numbers of eggs they contain. (Photo purchased in Japan by E. Gorton Linsley, 1930.)

(21) Superfamily SATURNIOIDEA Dyar 1902

KEY TO FAMILIES

1. Frenulum vestigial 2
 Frenulum wholly absent; hind wings with two anal veins; fore wings with M_1 separating from R beyond apex of cell; antennæ of males broadly pectinate for over half their length; maxillary and labial palpi small. Larvæ armed with spines and hairs and feed mostly upon foliage of broad-leaved deciduous trees. Adults medium or large. North American. (Royal Moths.) CITHERONIDÆ
2. Hind wings with Sc and R connected by cross vein, $r-m$; proboscis thin and reduced. Neotropical CERCOPHANIDÆ
 Hind wings with Sc and R_s not connected by $r-m$; wings often with transparent spots; antennæ of males fully pectinate. Larvæ often conspicuously armed with long hairs, tubercles, and spines. Adults medium to very large, loosely scaled and hairy moths. Cosmopolitan

and especially Neotropical and Ethiopian. (Giant Silk Moths, Wild Silkworms.) SATURNIIDÆ

Family SATURNIIDÆ (Harris 1841) Walker 1855 (Sat'ur-ni'i-dæ, from the Latin *Saturnus*, an ancient mythical god of seed sowing). German, Nachtpfauenaugen. Giant Silkworms, Wild Silkworms, Day Flying Moths.

Large to giant, stout, hairy, brightly and strikingly colored moths which are among the largest members of the order and of the INSECTA. The wings of many species have large transparent fenestræ or window-like areas. The entire nodies and bases of the wings are densely clothed with long soft hairs. Antennæ short and scaled only at the base; two pairs of pectinæ on each segment of both sexes, short in the females and strongly plumose in the males. Proboscis abortive. Maxillary palpi absent. Labial palpi short or absent. Wings very large, wide, hairy; frenulum absent, but humeral angles of the hind pair enlarged; usually with one anal vein; vein 7 connecting with 8 and 9; hind wings sometimes with tails (*Tropæa*, North America, and *Coscinoscera*, Australia) and vein C absent. Basal abdominal spiracles inconspicuous.

The adults are mostly nocturnal; the males are smaller than the females, about which they often assemble in considerable numbers. The smooth, rounded and flattened eggs are laid singly or in groups on the host plants. The caterpillars attain very large proportions and are furnished with *scoli* or spined tubercles and also in certain species with stinging hairs. They are frequently green with bright metallic spots that shine like jewels, and many assume a remarkably ferocious aspect. When mature they spin large silken cocoons which may be attached to leaves, stems, and branches of trees and shrubs, and in which the chrysalids often remain over winter. The adults emerge in the spring through a hole provided by the caterpillar or one made by softening the silk with a fluid secreted by the adults for this purpose.

The members of the family are large, conspicuous, beautiful, silk-spinning moths, many of which have long served man in the production of silk which has been obtained largely from wild and semidomesticated species. At least 30 such species are known to produce usable silk in oriental Asia. They are generally restricted to the moist temperate and tropical forested areas where an abundance of food is available for the large caterpillars. The larvæ feed chiefly on broad-leaved deciduous and evergreen trees and from one or two to four or five generations a year may occur in the different species.

Among the most important and interesting genera may be mentioned: *Actias* Leach, *Antheræa* Hübner, *Attacus* Linn., *Philosamia* Grote, *Samia* Hübner, and *Saturnia* Schrank. None of the species are truly domestic silkworms, but a number of the wild ones have been a source of silk for centuries and others have been at least partly cultivated and may be classed as semidomestic. Altogether they have contributed greatly to the benefit of mankind in providing strong, long-wearing, and warm fabrics. The eggs are usually laid in the late summer and fall and hatch in the following spring. The species are

uni- to multi-voltine (with one to five generations a year), depending upon the length of season and temperature of the localities in which they live. The cocoons are either closed or opened at one end.

Actias selene Hübner of China, Japan, India, and Ceylon feeds on native deciduous forest trees and shrubs and fruit trees and produces a silk that is used but little. The cocoons are thin, irregularly shaped, and closed.

The muga silkworm, *Antheraea assamensis* Helfer (= *assam* Westwood), is a wild and semidomesticated species which has been tended extensively in the



FIG. 162. Adult silkworm moths emerging from cocoons and mating. (Photo purchased in Japan by E. Gorton Linsley, 1930.)

Himalayas of India. It produces up to five generations a year. The caterpillars feed on *Machilus*, *Tetranthera*, *Symplocos*, and cinnamon, and produce white or amber ("muga" means amber) cocoons. A spine on each fore wing assists the moths in emerging from the cocoons in this and other members of the genus. Expanse 150–170 mm. The tasar, tusser, or tassah silkworm, *A. paphia* (Linn.) (= *mylitta* Drury), is a valuable wild and semidomesticated species with from one to two generations a year. The caterpillars feed on a wide variety of common broad-leaved trees — figs, oaks, crape myrtle, bér, asan, sal, etc. — and spin large suspended cocoons of brownish, reddish, or yellowish silk which is readily reelable. The species occurs in China, India, Ceylon, and parts of Malaysia. Expanse 140–190 mm. The Chinese oak silkworm, *A. pernyi*

Guérin, is another valuable wild and semidomestic species which has been collected and reared in China and Japan for centuries. It is easily cultivated in the open and was introduced into Europe in 1861. It feeds chiefly on deciduous oaks, has one or two generations a year, and produces the light buff Shantung silk. The Himalayan oak silkworm, *A. roylei* Moore, is another Indian oak-feeding species closely resembling the preceding with which it freely hybridizes in confinement. The white cocoons are encased in a hard envelope. Expanse 124–190 mm. The Japanese oak silkworm, *A. yamamai* Guérin, is an oak-feeding, wild and semidomesticated species in Japan. In the forests the caterpillars are watched on the native trees day and night until the cocoons are gathered. The silk is of very fine quality. The species was also reared for some years in Europe but, as in the case of all of these wild species, has been superseded by the common Chinese or mulberry silkworm.

The largest silk-producing moth is the Atlas moth, *Attacus atlas* (Linn.), which is not only one of the largest¹ lepidopterans but also one of the largest insects known if we consider actual surface area. The females may attain a wing expanse of 270 mm. (10½ in.). The color varies from buff almost to blackish-red, marked with white and various shades of tan, brown, black, and red. The huge caterpillars are somewhat pulverulent and feed on a number of plants as barberry, cinnamon, willow, *Falconia*, *Milnea*, apple, hornbeam, etc. They spin thick gray cocoons which are open at one end. The silk has been used for many purposes. The species occurs throughout southern Asia and Malaysia.

The ailanthus silkworm, *Philosamia cynthia* (Drury), and the race known as the arrindy silkworm, *P. ricini* (Boisduval), is the most important of the wild and semidomesticated species. It was very extensively utilized in its native home in China, India, Japan, and the East Indies, and was naturalized in Europe in 1861 and later in North America and Africa. The adults are olive and reddish-brown, have an expanse of 136–144 mm. The larvæ are green with black and blue tubercles and feed chiefly on ailanthus, castor bean, keseru, gulancha, gamari, and bér and to some extent also on barberry, wild cherry, laburnum, and lilac. From 75–90 pounds of leaf are required to make 1 pound of silk. In North America the species is established along the Atlantic coast. This moth has entered very extensively into the bulky literature on sericulture.

The only native silkworm of value in South America is *Rothschildia aurora* (Cramer), the silk of which was used extensively in northern South America from Brazil to Columbia, but the species ranges northward into Mexico. The goree or deomuga silkworm, *Theophila religiosæ* (Helfer) (= *huttoni* Westwood), is a wild species feeding on *Machilus* and *Ficus* in India. It is a large silkworm, the caterpillars attaining a length of 6½ in. being greatly exceeded in size by the Atlas moth. The caterpillars are beautifully colored, and the cocoons, which are 3 by 1½ in., are constructed of a coarse, strong silk used chiefly for making fishing lines.

¹ *Attacus edwardsi* White of Australia and *Coscinoscera hercules* Miskin of Australia and Papua are about the same size as this species but are not so well known.

In the history of sericulture in the north temperate regions, many attempts have been made in various parts of the world to find new sources of silk and especially to utilize the wild species which can be gathered in the forests. Particularly in Europe and North America wild silkworms have been utilized, but in all cases with only temporary success. In Europe the native **emperor moth**, *Saturnia pavonia* Linn., expanse 30–45 mm., is the only representative in Great Britain while *S. pyri* Schiffenmüller, expanse 60–75 mm., is the largest lepidopteran in Europe. The caterpillars feed on a wide variety of deciduous forest trees.

In North America a number of species have been tested for silk production but none has proved satisfactory. The **cecropia** or **emperor moth**, *Samia cecropia* (Linn.), the largest lepidopteran on the continent north of Mexico, has a wing expanse of 125–165 mm., is reddish with white lines and dusky wings, and occurs in the eastern areas. The caterpillars, 75–100 mm. long, bear six rows of spiny dorsal tubercles, and feed on a variety of deciduous trees and shrubs. The cocoons are very large and open at one end. The silk is very difficult to reel. **Glover's silkworm**, *S. gloveri* Strecker, is common in the Great Basin and the Rocky Mountain region, and the **ceanothus silkworm**, *S. euryalus* (Bdv.) (= *rubra* Behr), expanse 125–160 mm., and common on ceanothus, is the western representative. They are both univoltine and general feeders. The **spicebush silkworm** or **promethea moth**, *Callosamia promethea* (Drury), is the commonest large moth in eastern North America. The adults are black and dull red with pinkish markings and have an expanse of 75 mm. The caterpillars feed on a variety of deciduous trees and shrubs, especially spicebush, sassafras, sweet gum, and tulip. The cocoons are suspended. The **polyphemus moth**, *Teia polyphemus* Cramer, is a beautiful ocherous or buff and pink species with a wing expanse of 110–120 mm. which occurs throughout North America and is polyphagous on deciduous trees and shrubs. The closed cocoons are suspended and usually incorporate leaves and at least one stem. The silk is reelable but was never commercialized. One of the reasons no doubt is the presence of dipterous and hymenopterous parasites which very effectively reduce the number of all these large wild species. The **io** or **corn emperor**, *Automeris io* (Fab.), a large pinkish-brown and yellowish species, 60–80 mm. expanse, is also a general feeder which occurs east of the Rocky Mountains plains area from Canada into Florida. This genus is considered by some to be the most primitive in the family.

Other interesting members of the family are not classed as silkworms. The **luna moth**, *Tropæa luna* (Linn.), expanse 125–150 mm., is considered by many to be the most beautiful insect in North America. Its soft light-green color, purple-brown markings, eye spots, and long tails make it an object of great beauty and one desired by collectors the world over. The caterpillars feed chiefly on deciduous trees. The species inhabits the hardwood forests east of the Rocky Mountains from southern Canada to the Gulf of Mexico and is especially noted in the Ohio and Mississippi River valleys. The **buck moth**, *Hemileuca maia* Drury, a smoky-black species with markings of pale yellow,

white, and red and with an expanse of 50-65 mm., is an example of many species of this genus. The adults are swift-flying day moths that appear in late summer and fall. The spined larvæ feed on wild cherry, hazel, oak, willow,

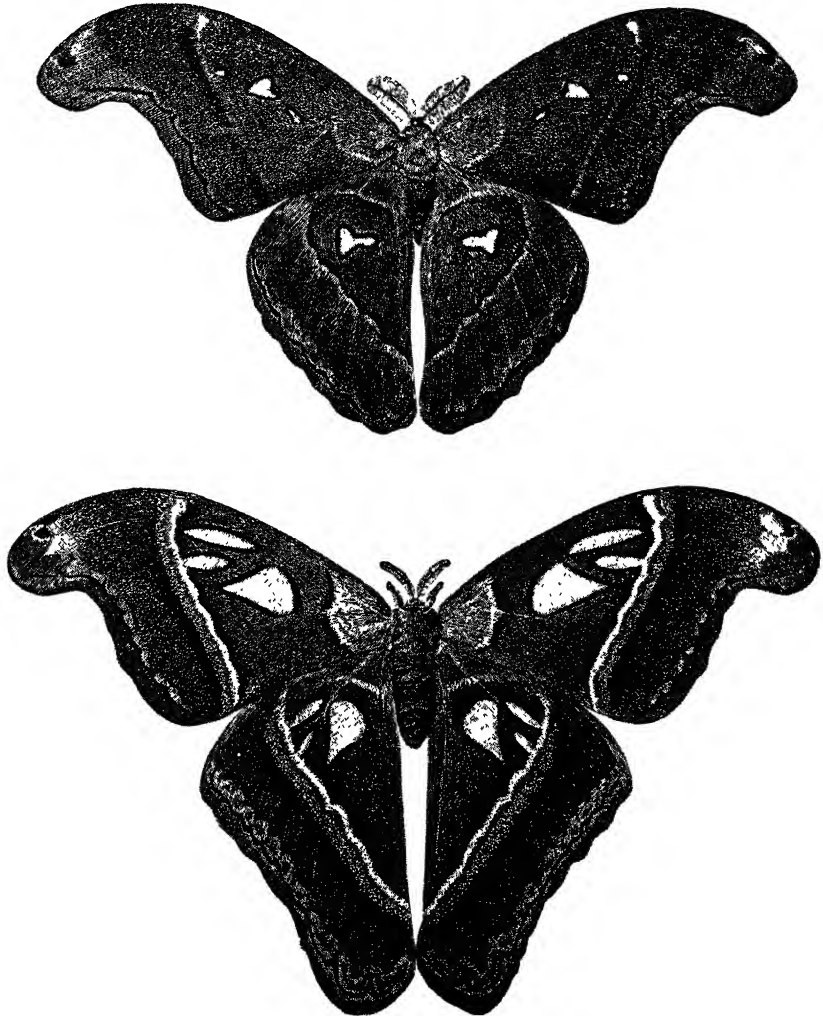


FIG. 163. The Atlas moth, *Attacus atlas* (Linn.), male and female. This giant moth may attain a wing expanse of 10 or more inches. It is indigenous to Southern Asia and Malaysia.

and other deciduous shrubs and trees and often do considerable damage as defoliators in North America east of the Rocky Mountains. The **pandora moth**, *Coloradia pandora* Blake, is a most interesting species. The adults are gray

with pinkish hind wings and an expanse of 75–100 mm. The large smooth green and brownish caterpillars feed on the needles of the yellow and Jeffrey pines in the western pine belt including the Rocky, Cascade, and Sierra Nevada Mountains. Two years are required to complete a generation, and the larvæ often appear in large numbers. They have for ages been collected, dried, and used for food by certain tribes of Indians, particularly in the Cascade and Sierra Nevada Mountains. The Indians obtain these larvæ by smoking the trees, causing the caterpillars to drop to the ground, or capture them in trenches as they descend to pupate in the litter and soil about the trunks of the trees.

Another giant species which should be mentioned is the *hercules* moth, *Coscinoscera hercules* Miskin of Australia and Papua, which is similar in general aspects to the Atlas moth, is dark brown in color, has a wing expanse of 270 mm. (10½ in.), according to Tillyard the greatest wing area of any moth in the world, and has short tails on the hind wings.

B. Division RHOPALOCERA Duméril 1806

KEY TO IMPORTANT SUPERFAMILIES

1. Antennæ widely separated at bases and in most, but not all, groups the club is prolonged into a recurved tip; R of fore wings five-branched and all branches arising separately from the cell. Larvæ usually naked and with a constricted neck. Adults have a short erratic and often swift flight. (Hesperiids, Skippers.) **HESPERIOIDEA**
- Antennæ close together at bases and the club more or less rounded apically and never hooked; R₄ and R₅ of fore wings stalked. Larvæ and adults exceedingly variable. (Butterflies.) . . . **PAPILIONOIDEA**¹ p. 499

(22) Superfamily HESPERIOIDEA Wallengren 1853

KEY TO FAMILIES

1. Hind wings with cell divided by forked base of M; M₂ well developed; male with frenulum. A single archaic Australian species, *Euschemon rafflesia* W. S. M. **EUSCHEMONIDÆ**
- Hind wings with the base of M absent; M₂ somewhat reduced or absent 2
2. Head narrower than metathorax; antennal club large, not extended into a point or a hook; wing expanse 40 mm. or more. (Giant Skippers.)
MEGATHYRIDÆ
- Head large; antennal club usually extended to a sharp point and crook; wing expanse less than 40 mm. (Skippers.) **HESPERIIDÆ** p. 497

¹ The superfamily NYMPHALOIDEA is separated from the PAPILIONOIDEA by Tillyard (1926).

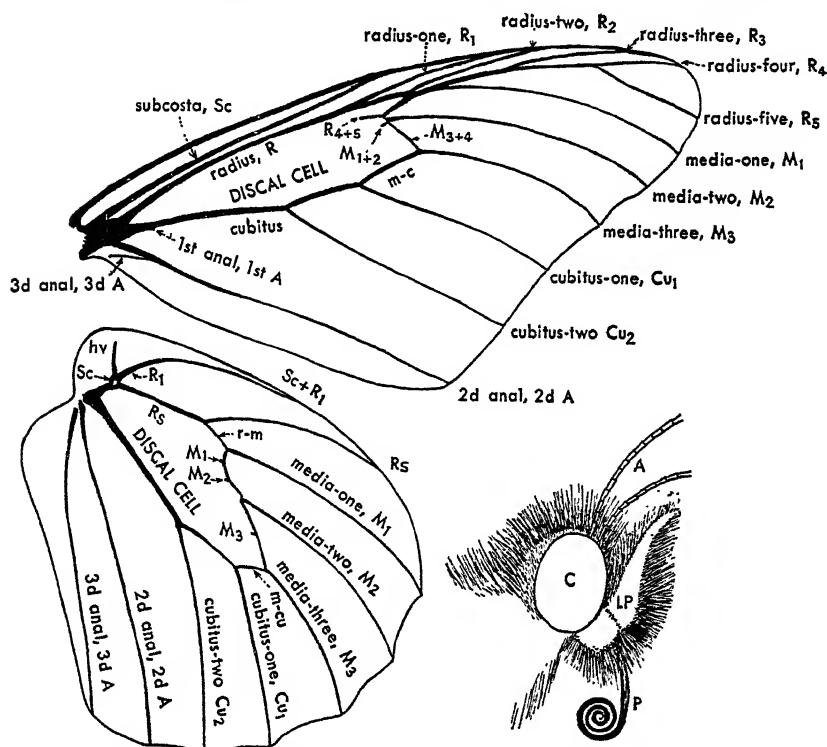


FIG. 164. Wing venation of the monarch butterfly, *Danaus menippe* (Hübner), and head of same. A, antenna; C, eye; P, proboscis or maxillae; LP, labial palpus. (From *Insects of Western North America*.)

Family **HESPERIIDÆ**¹ Leach 1815, 1819 (Hes'per-i'i-dæ, from the Greek Ἑσπερίδες, daughters of the night or evening; referring to the crepuscular habits of the adults and nocturnal habits of the larvæ). German, Dickköpfe. French, Hespériidés. Skippers.

Small to medium-sized, short, stout, mostly somber-colored butterflies which frequently hold the wings partly opened at rest. The bodies and wings are often quite hairy and scaly; the colors are various combinations of black, gray, brown, tan, and orange, and some forms are brilliant and metallic. Head large; antennæ clavate and hooked beyond the apical club and ending in a dull or sharp point; eyes partly covered with hairs; palpi three-segmented, porrect or upturned. Fore wings with all the veins separated; frenulum and frenulum hook normally absent. Forelegs well developed in both sexes; tibiæ usually spurred, fore pair also with pads; claws short and thick; empodium present;

¹ The members of this family have also been placed in the family **URBICOLIDÆ** Tutt 1906 and in the separated suborders **NETOCERA** Haase 1891, Spuler 1908, and **GRYPOCERA** Reuter 1896, Seitz 1909.

middle tibiae one-spurred; hind tibiae two-spurred. Sexual and seasonal dimorphism present; males may have patches of androconia on the upper surface or along the costal margins of the fore wings. Eggs subspherical, smooth or sculptured, laid singly on hosts. Caterpillars naked; flattened or subcylindrical; head large and frequently widest anteriorly, with paired processes; body narrowed anteriorly to form a slender neck; five pairs of prolegs present. They live exposed on the plants or in rolled and webbed leaves. Many of them are

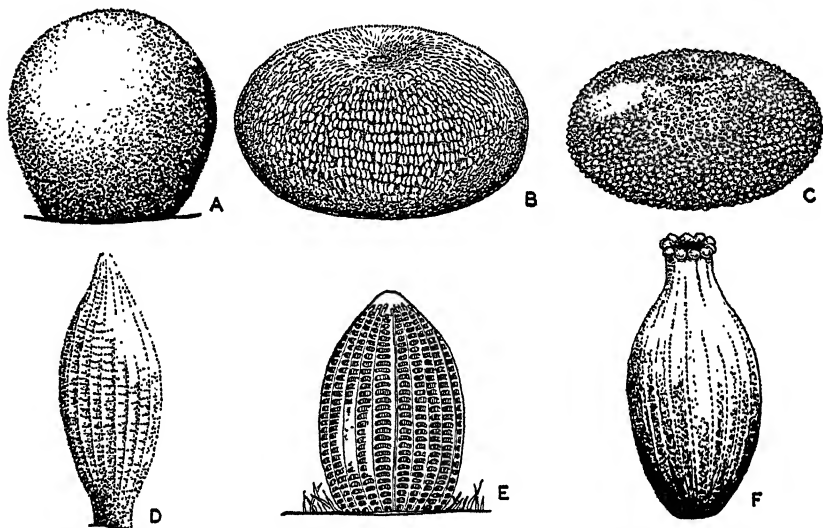


FIG. 165. Eggs of butterflies. A, western parsley butterfly, *Papilio zelicaon* Lucas; B, *Parnassius smintheus* Doubleday and Hewitson; C, bean lycænid, *Strymon melinus* (Hübner); D, alfalfa butterfly, *Colias eurytheme* (Boisduval); E, monarch butterfly, *Danaus menippe* (Hübner); F, pine butterfly, *Neophasia menapia* (Boisduval). (Redrawn from J. A. Comstock, 1927.)

nocturnal. While they feed upon a wide variety of hosts, they subsist chiefly upon cereals, grasses, palms, and other monocotyledons as well as many dicotyledons, especially legumes.

The chrysalids are oval-cylindrical, smooth, usually rounded, dull-colored, attached by a cremaster, and usually in a thin loose cocoon of silk and leaves or debris.

The adults are rapid and erratic fliers and are among the commonest butterflies throughout the meadows during spring, summer, and fall months. Their somber colors and peculiar attitudes are responsible for their being called moths by those who do not know how to separate butterflies from moths.

The family consists of about 3,000 species which are scattered throughout the tropical, subtropical, and temperate regions. They occur on all the continents, but it is worthy of note that whereas there are 92 indigenous species in Australia there are none native to New Zealand. According to Tillyard

(1926) probably the most remarkable and archaic existing species is the **Australian regent skipper**, *Euschemon rafflesia* MacLeay, in which both the frenulum and retinaculum are present in the males. The gregarious larvæ web the leaves of the host, *Wilkiea*. The larvæ of *Eantis thraso* Hübner are striped green and yellow and are injurious to citrus in the West Indies. Leaves are used as shelters for the caterpillars and chrysalids.

One of the commonest North American species is the **Northern dusky wing**, *Thorybes pylades* Scudder, expanse 35–40 mm., yellowish-brown with white spots, which ranges from South America into Canada. The **gray skipper**, *Pyrgus communis* Grote, feeding on malva, and the **field skipper**, *Atalopedes campestris* (Bdv.), feeding on grasses, occur throughout much of North America.

(23) Superfamily PAPILIONOIDEA Dyar 1902

KEY TO IMPORTANT FAMILIES

1. Forelegs normal and functional; if reduced in size the claws toothed or bifid 2
Forelegs, particularly in the male, specialized and not used for walking; claws, when present, neither toothed nor bifid 4
2. Claws large, neither toothed nor bifid; fore tibiæ with pads; fore wings with Cu apparently four-branched and with two or three anal veins; anal area of hind wings reduced and but one anal vein present . . . 3
Claws bifid; fore tibiæ without pads; fore wings with Cu apparently three-branched and with two anal veins. Small to medium-sized butterflies; yellow, orange or white marked with black (Whites, Orange-tips, Sulphurs, Brimstones, etc.) **PIERIDÆ** p. 506
3. Fore wings with radius five-branched, anal cross vein present; margin of hind wings often wavy or notched and extending backwards into one or more pairs of prolongations or tails. Large showy butterflies. (Swallowtails, Papilios, Orange Dogs.) **PAPILIONIDÆ** p. 500
Fore wings with radius four-branched, without anal cross vein; tails absent. Medium-sized alpine butterflies; colors, white or cream marked with black and with round red or yellow spots **PARNASSIIDÆ** p. 505
4. Forelegs much reduced in size in both sexes and folded against thorax and not used for walking; tarsi one-segmented in male and five-segmented in female; claws absent; fore wings with radius five-branched 5
Forelegs of female used for walking and each with two claws; those of male reduced and each with a single claw; fore wings with radius three- or four-branched 9
5. Hind wings with discal cell closed by distinct vein 6
Hind wings with discal cell open or closed by an indistinct vein . . . 8
6. Fore tarsi of female terminating in a furrowed knob; fore wings with A_3 present; antennæ without scales. Large, brightly colored butterflies. (Monarchs and Milkweed Butterflies.) **DANAIDÆ** p. 508
Fore tarsi of female somewhat abbreviated; fore wings with A_3 absent 7

7. Fore wings with certain veins greatly swollen at the base. Medium-sized dull-colored butterflies frequently tawny, brown, gray, or dusky and with eyespots; feeble fliers; cosmopolitan. (Satyrs, Graylings, Meadow-browns, Heaths.) **SATYRIDÆ** p. 510
 Fore wings without greatly swollen veins. Neotropical **BRASSOLIDÆ**
8. Hind wings depressed along the anal margins to embrace the abdomen. Large brilliant and metallic, often blue, tropical butterflies much used in the arts. (Morphos.) **MORPHOIDÆ** p. 510
 Hind wings without anal depressions. Medium-sized to large vari-colored butterflies common throughout the world (Fritillaries, Crescent Spots, Anglewings, Four-footed Butterflies, Brush-footed Butterflies.) **NYMPHALIDÆ** p. 511
9. Costa of hind wings thickened to meet the humeral angle; Sc with basal spur or humeral vein. Neotropical. (Metal Marks.) **RIODINIDÆ**
 Costa of hind wings not thickened at base; humeral vein absent. Small to medium-sized common butterflies; mostly metallic blue above, variable below. (Gossamer-winged Butterflies, Blues, Coppers, Hairstreaks.) **LYCÆNIDÆ** p. 513

Family PAPILIONIDÆ Leach 1819 (Pa-pil'i-on'i-dæ, from the Latin *papilio*, butterfly). German, Edelfalter. French, Papilionidés. Swallowtails, Bird-winged Butterflies.

Beautiful large, brightly colored butterflies which are among the finest of all living creatures. Mostly iridescent black or very dark blue or green with bright

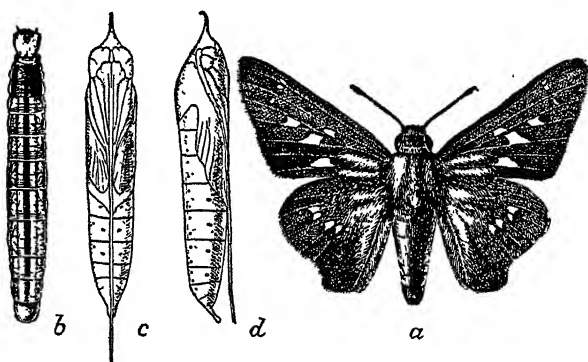


FIG. 166. A skipper butterfly, *Calpodus ethlius* (Cramer). *a*, adult; *b*, caterpillar; *c* and *d*, chrysalids with long sheathed rostrums. (After Chittenden, U.S.D.A. from *Insects of Western North America*.)

yellow, orange, red, green, or blue markings; antennæ strongly knobbed; legs fully developed; wings very large; hind pair with the vein 1A absent; with or without one or two pairs of rather short, variously shaped tails which are marginal extensions of the region of the vein M3 of the hind wings. *Papilio*

polydamas Linn. of the southern states has no tails; but the majority of the American species has one tail on each hind wing; *P. daucus* Bdv., the largest western species, has two tails; and the rare southwestern *P. pilumnus* Bdv. has three tails on each.

Sexual color dimorphism is common in either or both sexes, and seasonal color dimorphism also occurs in a number of species in which different color forms occur in the early spring, late spring, and summer. Polymorphism is very common and gynandromorphism¹ occasionally occurs.

The eggs are usually spherical, smooth, and are attached singly in few or in large numbers on the host plants. The caterpillars are large, fleshy, smooth, with or without fleshy dorsal and lateral tentacle-like processes; the thoracic region is often enlarged, with two large eyespots, and some species possess an *osmeterium* or Y-shaped odorous protrusile scent organ from a slit on the dorsum; frequently polymorphic in some species, the larvæ assuming three or more color phases in development. Chrysalids naked, somewhat rugose or sculptured; angular, with the anterior region truncate (kite papilios) or bifurcate (fluted papilios); mid-dorsal metathoracic horn present or absent; abdomen may have a pair of hard tubercles on segments IV to VII; attached by cremaster and a girdle with the head up. Hibernation is in the pupal stage in the temperate regions.

These large butterflies are largely tropical forest species which have invaded the subtropical and temperate regions. They are highly prized by collectors and are protected by law² in certain areas. The family is composed of two important genera *Papilio* Linn., or swallowtails, and *Troides* Hübner 1816 (= *Ornithoptera* Boisduval 1833), or bird-winged butterflies. The latter are chiefly Malaysian. There are some 850 described species. The genus *Papilio* is well represented in North America with at least 25 species north of Mexico. The larvæ are general feeders but they show marked preferences for certain genera or species of host plants and may be loosely grouped according to food habits.

- (1) Feeding on *Aristolochia* or pipevine. These are known as pipevine swallowtails.

Papilio philenor Linn. (also on *Asarum* or wild ginger). Temperate North America.

“ *polydamas* Linn. Southern North America.

“ *priamus* Linn. Australia.

Eurycus cressida Fab. A peculiar species with nearly transparent wings. Australia.

- (2) On *Citrus*, citron, lemon, limes, oranges, etc. The larvæ are commonly referred to as orange dogs or orange puppies. They are polymorphic,

¹ This phenomenon may occur throughout the order.

² In Wicken Fen Nature Reserve, in the parish of Wicken, Cambridgeshire, England, the single English representative, *Papilio machaon* Linn., the larvæ of which feed on umbelliferous plants, is so protected by law and by permit, but a single specimen is allowed each collector a year. With this protection the butterfly lives a precarious existence and is looked upon as a rarity.

and the first stage looks like a bird dropping. They also feed upon other hosts which in most cases may be regarded as primary.

Papilio ægus Donovan. Australia.

" *anactus* MacLeay. Australia.

" *demodocus* Esper. Africa, Madagascar.



FIG. 167. Young and mature forms of the western parsley caterpillar, *Papilio zelicaon* Lucas. (From *Insects of Western North America*.)

Papilio nireus Linn. Africa—Sierra Leone.

" *demoleus* Linn. India, Ceylon.

" *pammon* Linn. India.

" *polymnestor* Cramer. India.

" *polytes* Linn. Tropical Asia.

" *andramon* Hübner. North America — West Indies.

" *cresphontes* Cramer. North America — tropical and sub-tropical.

- Papilio pelaus* Fab. North America — West Indies.
 “ *thoas* Linn. (and varieties). Tropical North and South America.
 “ *zelicaon* Lucas. North America — western.
- (3) On UMBELLIFERÆ, parsley, celery, carrots, poison hemlock, water hemlock, sweet fennel, etc. These plants may be alternate hosts for many species including some on *Citrus*. Larvæ commonly polymorphic.
- Papilio ajax* Linn. Parsnip swallowtail. North America — eastern.
 “ *bairdii* Edwards. North America — southwest.
 “ *brevicauda* Saunders. North America.
 “ *demodocus* Esper. Common in South Africa, Madagascar.
 “ *machaon* Linn. European swallowtail. Europe, northern Asia, and northern North America. Common.
 “ *zelicaon* Lucas. North America — western.
- (4) Various Shrubs and Trees. Temperate species. Caterpillars somewhat variable in color but mostly greenish and with large thoracic eye-spots.
- Papilio daunus* Bdv. the largest western North American species, with 100–140 mm. expanse; on ash, cherry, chokecherry, plums.
 “ *eurymedon* Bdv. on *Rhamnus* and *Ceanothus*. Western North America.
 “ *cresphontes* Cramer, on prickly ash and hop tree. Tropical North America.
 “ *glaucus* Linn.,¹ the yellow swallowtail; on cherry, plum, and other ROSACEÆ in eastern North America.
 “ *marcellus* Cramer, the Zebra swallowtail; on papaw in eastern North America.
 “ *palamedes* Drury, the *palamedes*; on magnolia in southeastern North America.
 “ *rutulus* Lucas, the commonest species in western North America; on fruit trees, wild cherry, plum, berries, and other ROSACEÆ, and quite abundant on the elms and ornamental sycamore or plane trees in cities and parks.
 “ *thoas* Linn.; on prickly ash and hop tree in eastern and southern United States and Mexico.
 “ *troilus* Linn., spicebush swallowtail; on laurel, sassafras, and spicebush in eastern North America.

There are a number of very interesting tropical species. N. D. Riley (1931), Keeper of Insects in the British Museum of Natural History, thinks the African swallowtail, *Papilio dardanus* Brown, is in many ways the most remarkable

¹ The common yellow or tiger swallowtail, *P. glaucus* Linn. (= *turnus* Linn.), was the first American butterfly ever to be illustrated, a rough drawing appearing in the early English work, *Insectorum sive Minimorum Animalium Theatrum*, by Tho. Moufet, published in London in 1634. A copy of the title page of this work appears as the frontispiece to this book. (See Holland, 1931, pp. 304–307.)

butterfly in the world because of its numerous colors and other aberrations which offer splendid examples of Batesian mimicry to the extent of mimicking three widely separated distasteful species and in the absence of tails in the females although the males have short ones.

The bird-wing butterflies are among the most magnificent members of this family. The fore wings are very large while the hind pair may be quite small

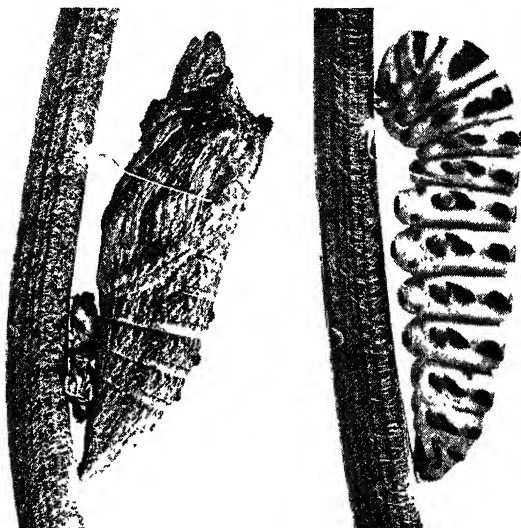


FIG. 168. The western parsley caterpillar. Right, larva has just attached itself by a tuft of silk at the posterior end (cremaster) and by a thoracic girdle in preparation for pupation; left, chrysalis or pupa of the same a few hours later and with the cast larval skin visible beneath. (From *Insects of Western North America*.)

in comparison. Among the finest species are *Troides amphrysus* (Cramer), expanse 114 mm., a marvellous combination of very dark brown and brilliant primrose yellow; occurring in Malacca and Java. *T. brookiana* (Wallengren), expanse 130 mm., a remarkable species with long narrow wings; rich velvety black with a lateral row of seven large pyramidal-shaped lucid green spots on the fore wings, a large green patch near the base of each hind wing, and the pronotum and other small thoracic areas dull red, is widely distributed in Malaysia. *T. primas* (Linn.), expanse 140 mm., a striking polymorphic species in which the common form is rich blackish-brown with the submarginal borders of the fore wings and most of the hind wings brilliant green and with two small spots on the anterior margin of the hind wings and the abdomen yellow. The variety *cræsus* Wall. has a similar combination of orange red, yellow, and black, and the var. *urvillianus* (Guérin) is azure blue, yellow, and black. It also is Malaysian.

Family PARNASSIIDÆ Swainson 1840 (Par'nas-si'i-dæ, from the Greek *παρνασσιος*, belonging to the mountain Parnassus in Greece; in reference to their mountainous habitats). Parnassians, Apollos.

A small group of mountainous, alpine, and subarctic butterflies which are usually translucent white, partly or almost completely marked with brownish-gray generally diffused or as borders, and spots on the wings and usually with



FIG. 169. Adult or butterfly of the western parsley caterpillar. (From *Insects of Western North America*.)

circular pink, orange, or red spots on the hind wings and often also on the fore wings. One Alaskan species *Parnassius eversmanni* Ménétriés is sexually dichromatic: the females being normally whitish and the males yellowish. The antennæ are straight, relatively short, and distinctly knobbed; palpi slender, straight, hairy. The male sperm pouch is sometimes affixed to the female in copulation and may be carried by the latter for some time. The eggs are turban-shaped and sculptured. The caterpillars are somewhat flattened, pilose, with small heads, dark and marked with small white or colored spots. The chrysalids are short and cylindrical and occur on the surface of the ground or in litter. The caterpillars of known species feed chiefly on plants belonging to the genera *Corydalis*, *Saxifraga*, and *Sedum*.

There are three species common to Europe: the apollo butterfly, *Parnassius apollo* (Linn.), the black apollo, *P. mnemosyne* (Linn.), and *P. phæbus* (Fab.), while in North America the most important species are *P. clodius* Ménétriés and its varieties in the northwest and *P. smintheus* Doubleday and Hewitt in the northern and alpine regions of the continent. The last was the first named of the North American species. *P. delius* Esper, *P. nominulus* Staudinger, and *P. nomion* Frisch occur in Alaska and the first in Siberia also.

Family PIERIDÆ¹ (Boisduval 1836) Duponcel 1844 (Pi-er'i-dæ, from the Greek *πῆρις*, a muse). German, Weisslinge, Gelblinge. French, Piéridés. Whites, Yellows, Orange Tips, Brimstones, Sulphurs.

Medium-sized, mostly white and various shades of orange and yellow common diurnal butterflies further characterized by dark and brightly colored margins of the wings. The eyes are naked and without white circles. Antennæ with few or no scales and conspicuously knobbed. Palpi short or longer than the head. Legs fully developed, the claws bifid or toothed. Wings thinly scaled; the dorsal areas generally marked along the apical borders and sometimes with a pair of median spots on each pair; fore wings with subcostal, having five or six nervules and upper radial vein absent; hind wings with one or two anal veins; undersides cryptic-colored or marbled. Color-sexual dimorphism and polymorphism is common, and seasonal dimorphism also occurs in the family. The eggs are naked, spindle-shaped or somewhat pyramidal, with vertical ridges and cross striæ. They are attached singly or in rows or groups on the hosts. The caterpillars are rather slender, naked, granulate, or pilose, without tentacles, tubercles, or special scent organs; segments annulate; crochets of prolegs arranged by two's or three's in series. They are mostly cryptic green, yellowish, or dusky, often with small dark granules or stripes, and are frequently gregarious. Those of the Australian *Delias harplyce* Donovan surround the leaves with a thin web, upon which the chrysalids are attached. The chrysalids are elongate, angular, usually with a single head prolongation or spine; cryptically pale, yellowish, or green-colored; and freely attached by a cremaster and girdle in a horizontal or vertical position with the head up. There are usually two generations a year, but some tropical species have as many as six. The adults are active and abundant particularly in the spring and the autumn and commonly hibernate during the winter, many of them frequently covered by snow and ice. They oviposit on many kinds of host plants but are specially partial to those of the families CRUCIFERÆ, CAPPARIDACEÆ, and the LEGUMINOSÆ, upon which the larvæ feed.

This fairly large family, consisting of some 1,000 species which are mostly tropical and subtropical, is particularly well represented in the Neotropical, Indian, and Ethiopian regions, but many species have invaded the temperate and a few the alpine and subpolar regions. A number of species (*Catopsila* Hübner) of South America and India migrate in considerable numbers, and many of the subtropical forms have seasonal migrations into and out of the cooler temperate and alpine areas.

The most noted species is the cosmopolitan cabbage butterfly, *Pieris rapæ* (Linn.) which has a wing expanse of 30-50 mm., is white with the tips of the fore wings black, the female with two and the male with one black spot, and the hind wings of both sexes with a single black spot on the outer front margin. It is a common injurious pest of cabbages and other cultivated cruciferous

¹ Frequently relegated to subfamily rank under the family PAPILIONIDÆ by many authors. The above family name is also considered to be a synonym of ASCIIDÆ (ASCIDÆ Hampson 1918) by others.

crops. An Old World species, it was introduced into Quebec, Canada, in 1858 and reached California about 28 years later. It is commonly called the turnip butterfly in Europe. The cabbage butterfly of Europe is *P. brassicae* (Linn.), expanse 29–34 mm., which is very similar to the preceding species. The rape butterfly, *P. napi* (Linn.), expanse 20–25 mm., white with black and clouded wing veins, is common to both Europe and North America. The southern cabbage butterfly, *P. protodice* Bdv. and Lec., also has the veins and margins

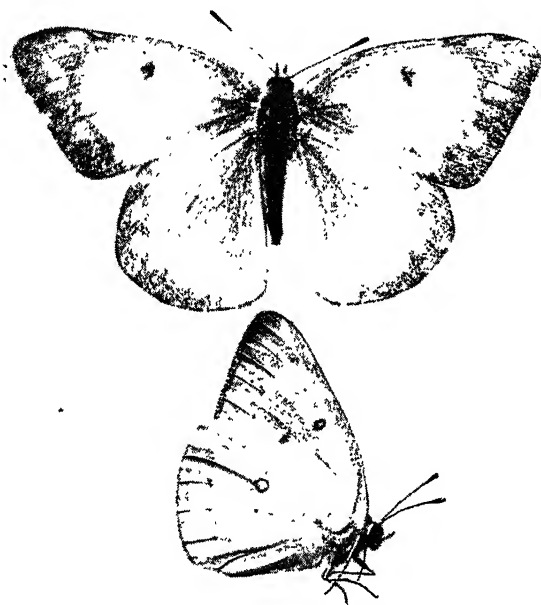


FIG. 170. The common yellow alfalfa butterfly, *Colias eurytheme* (Boisduval). (From *Insects of Western North America*.)

bordered and dusky but is limited to the eastern and southern parts of the United States and is being gradually replaced by *P. rapæ* (Linn.).

The western pine butterflies, *Neophasia menapia* Falder and Falder and *N. terlootii* Behr, are similar to some of the above in color but with blacker borders. The larvæ feed on pines and the adults are limited to forest regions along the Pacific coast.

The alfalfa butterfly, *Colias eurytheme* (Bdv.) (*Eurymus*), expanse 40–60 mm., is a yellow polymorphic species of various shades of pale yellow to bright orange-yellow, with four median orange spots and dusky outer wing margins. It is common and abundant throughout North America and the most important pest of alfalfa in the southwest.

One of the finest European species is the brimstone or lemon bird, *Gonepteryx rhamni* (Linn.), expanse 25–30 mm., a polymorphic species varying from pale yellow to bright orange-yellow and always with four median orange spots. The fore wings are pointed. The larvæ feed on *Rhamnus*. The great sulphurs, *Callidryas* Bdv., of tropical America are species comparable in color but larger. The cloudless sulphur, *C. sennæ* (Linn.), ranges throughout eastern North America and southwards to the tip of South America. *Terias hecabe* (Linn.) in India and *T. smilax* Donovan in Australia are the commonest species. Tillyard (1926) believes the Australian *Delias mysis* (Fab.), pure white with black and scarlet margins, to be the most colorful member of the family.

Family DANAIDÆ¹ Hampson 1918 (Dan-a'i-dæ, from the Greek *Δαναΐς*, any one of the 50 daughters of Danaüs in Greek mythology). Milkweed Butterflies. Wanderers.

Large brightly colored butterflies which are frequently orange-brownish with black markings. Antennæ without distinct dorsal scales; club small or vestigial. Fore tarsi of female terminating in a ridged knob; fore wings with subcostal vein forked at base. Sexual dimorphism occurs in which the males are frequently smaller, differently colored, and with scent glands in small definite areas on the hind wings, and with protrusile anal tufts or brushes for distributing the odors. Seasonal dimorphism is also evident in the color patterns. The larvæ are usually smooth and with from two to four pairs of tentacle-like, fleshy processes, one pair on the thorax and the rest on the abdomen. The chrysalids are short, cylindrical, naked, smooth, and frequently have beautiful soft colors marked with silver and gold; suspended by cremaster with head downwards.

One of the commonest and most widely distributed species is the milkweed butterfly, the wanderer or monarch, *Danaus menippe* (Hübner) (= *archippus* Linn., *plexippus* Fab.), a beautiful large orange species with black and white markings and an expanse of 90–100 mm. The eggs are conical-ovate, 1.2 mm. high and half as broad, with 22 vertical ribs, and pale amber-green in color. The mature caterpillars are 45 mm. long, yellowish-green with numerous, entire and short, narrow, black bands and black legs. On the dorsum of the body segments II and VII is a pair of long black whiplash filaments that twitch rapidly when the larva is disturbed. The chrysalis is exquisite jade green with a black and gold line around the greatest diameter and further ornamented with spots of burnished gold. The eggs are laid singly on the leaves of milkweed, *Asclepias* spp., upon which the larvæ feed exclusively. This is a nearly cosmopolitan species occurring throughout much of the world. In California the adults hibernate in large swarms chiefly on cypress and pine trees along the coast from Sonoma County southward.² On sunny days they become active but congregate at night and during dull and rainy weather. Mating

¹ Synonyms are: LIMNADIDÆ, ACRÆIDÆ, EUPLÆIDÆ, MANIOLIDÆ.

² In certain areas, notably Pacific Grove, the butterflies are protected by law from disturbance or capture.



FIG. 171. The monarch butterfly, *Danaus menippe* (Boisduval), hibernating in great numbers on an oak tree. One of the insect groups in the American Museum of Natural History, New York. (Photo courtesy American Museum Natural History.)

begins in early March and dispersal follows soon afterwards, the adults moving to the valleys, mountains, and northwards.

Danaus chrysippus (Linn.) is one of the commonest butterflies in South Africa and southern Asia. It also feeds on *Asclepias*. Members of two other genera mimic it. *D. genutia* Cramer is the oriental species.

Euplaea core Cramer, a dark-brown butterfly with white wing spots, is also widely distributed. The caterpillars feed on oleander and *Ficus*.

Family SATYRIDÆ (Boisduval 1832) Swainson 1840 (Sa-tyr'i-dæ, from the Greek Σάτυρος, a Satyr, Mythological deity). German, Augenfalter. French, Satyridés. Satyrs, Meadow Browns, Heaths, Graylings, Marbled Whites.

Small to medium-sized butterflies which are usually somber or cryptic shades of gray and brown although certain tropical and Australian species are brightly colored; a variable number of large and small annular spots or eyespots singly or in a row inside the margins of the wings; clothed with soft, hair-like scales. Antennæ feebly knobbed. Palpi strongly depressed. Wings hairy; rarely transparent in the South American genera *Cithærias* Hübner and *Hætera* Fab. Fore wings with bases of certain veins greatly swollen. Sexual dimorphism occurs in some species. The caterpillars are fusiform, green, yellow, brown, or cryptic. Head normal, bilobed, or horned. Thorax constricted and neck-like. Body segments annulate, with papillate setæ and a pair of anal processes (split tail). A few species make cocoons. Chrysalids naked; suspended head downward by a cremaster; a few are subterranean. The larvæ live largely on grasses and cereals and occur in open plains, meadows, and mountains. The adults are feeble or strong fliers and, being shade-loving, frequent woodlands and brushlands. They also occur at altitudes up to 12,000 ft. in the Rocky Mountains, and members of the genus *Eneis* Hbn. range into the polar regions. Some tropical species are crepuscular.

At least 60 species occur in North America, many of which are commonly called graylings. The grayling, *Minois alope* (Fab.) (*Cercyonis*), expanse 50–65 mm., occurs throughout the continent. The White Mountain butterfly, *Eneis melissa* Fab., expanse 40–43 mm., marbled dark brown and pale gray, inhabits the high mountains and the northern parts of the continent.

The rice butterflies, *Melanitis leda* (Linn.) and *Mycalesis gotama* Moore, are pests of rice and the former also of barley, bamboo, and sugar cane in Japan (Clausen, 1931) and Asia.

The family is well represented in Australia by many beautifully colored species.

Family MORPHOIDÆ (Boisduval 1836) Kollar 1850 (Mor-pho'i-dæ, from the Greek Μορφή, an epithet of Venus). Morphos.

Splendid, large, brilliant, metallic butterflies of tropical America and northern India. The upper surfaces of the wings are often blue and remarkably iridescent, the colors being due to the presence of minute ridges and striæ on the

surfaces of the scales that reflect the light rays so as to cause complex interferences with each other and produce the brilliant colors which are as permanent as are the structures producing them. For this reason these beautiful insects are captured in wasteful numbers for many uses in the arts. So great has become the demand that several countries have sought to protect the butterflies from destruction and possible extermination, which seem certain unless action is immediate and effective. The adults are characterized by the hind wings, which have a long depression on the anal margins in which the abdomen rests, and by the open discal cell. The larvæ are variable, and gregarious forms often appear like orchids, bird droppings, or other objects on the trunks of trees.

The family is confined to tropical forests where the adults soar about among the trees. The two important genera are *Amathusia* Fab. (Indo-Malayan) and *Morpho* Fab. (Neotropical). *Morpho menelaus* (Linn.) of tropical South America is a large, beautiful opaline blue and black popular commercial species. *M. cypris* Westwood, a combination of brilliant light blue, white, and black, of Central and tropical South America, is one of the most beautiful species. *M. sulkowskyi* Kollar appears transparent and iridescent pink and blue with a series of four indistinct double blue circles on each wing. The body and wing margins are brownish and there are two small scarlet spots on the anal angles of the hind wings. It has been taken in Colombia and Peru. *M. achilles* (Linn.) is a large brownish-black species with large blue transverse bands crossing both pairs of wings.

Family NYMPHALIDÆ Swainson 1827 (Nym-phal'i-dæ, from the Greek *νύμφη*, nymph). German, Fleckenfalter. French, Nymphalides. Brush-footed Butterflies, Nymphalids, Fritillaries, Anglewings, Sovereigns, Emperors, Tortoiseshells, Peacocks, Leaf Butterflies.

Medium to large, mostly brightly colored butterflies often dull and cryptic or with warning colors. Antennæ knobbed. Palpi large and clavate. Wings large; subcostal cell rarely present; discal open or closed by a veinlet. Forelegs greatly reduced; in males bush-like and the tarsi one-segmented; in females comb-like, with four to five segments and without claws; tibiæ short and hairy. The forelegs, according to Ilse, are used for drumming on the host plant prior to egg laying. Sexual and seasonal dimorphism are common. This, one of the dominant families of butterflies, includes more than 4,000 described species. The eggs are scattered over the host plants singly or in small groups. The caterpillars are naked or usually spiny and obscurely or strikingly marked. The chrysalids are naked, angularly tuberculate, suspended by the cremaster head downwards; dull or marked with silver or gold.

The commonest and most cosmopolitan butterfly, the painted lady, *Vanessa cardui* (Linn.), belongs to this family. It often migrates in enormous swarms. The red admiral, *V. atalanta* (Linn.), and the painted beauty, *V. virginiensis* Drury (= *huntera* Fab.), are also widely distributed in the Holarctic region. The peacock, *Vanessa io* (Linn.) of Europe, and the buckeye, *Junonia cænia* Hübner of North America, are familiar butterflies with large eyespots on the

wings. The purple emperor, *Apatura iris* (Linn.), which feeds on willow in Europe, and the tawny emperor, *Asterocampa clyton* Bdv. and Lec., which feeds on hackberry in eastern North America, are well-known species. The mourning cloak or Camberwell beauty, *Nymphalis antiopa* (Linn.) (*Aglais*), the familiar brownish-black butterfly with yellow wing borders, is known to all students of natural history in the Holarctic region. The larvæ feed on willow and elm, and the adults hibernate and are often active on sunny winter days.



FIG. 172. The red admiral butterfly, *Vanessa atalanta* (Linn.), a cosmopolitan species. (From *Insects of Western North America*.)

The tortoiseshells, *N. milberti* (Godert) on nettle and *N. j-album* (Bdv. and Lec.), on nettle, hop, elm, and false nettle, are restricted to northern North America and get their common names from the variegated markings on the undersides of the wings. The California tortoiseshell, *N. californica* (Bdv.), on ceanothus and other hosts, sometimes appears in tremendous numbers in western North America. The fritillaries belonging chiefly to the genera *Argynnis*, *Melitæa*, *Euptoieta*, and *Brenthis* are beautiful orange-brown above and silver-spotted underneath the wings. They are temperate species often abundant in mountainous regions. The gulf fritillary,

Dione vanillæ (Linn.), a beautiful orange-brown species with large silver spots on the undersides of the wings, is common on passion vine in tropical and subtropical North and South America.

A very common butterfly in western North America is the checkerspot or chalcedon, *Euphydryas chalcedona* (Doubleday and Hewitt) (*Lemonias*), expanse 45–65 mm., black with numerous yellow and orange-brown spots. The caterpillars are 30–40 mm. long, bluish-black with orange markings and with spines borne on numerous tubercles. The chrysalids are pale fawn with black

markings and hang by the cremaster. The caterpillars are gregarious, hibernate in the first or second instars in small webs on the host plants, and are often sufficiently abundant to strip large areas of vegetation. They feed on a wide variety of native and cultivated plants but are specially fond of those belonging to the family SCROPHULARIACEÆ.

Family LYCÆNIDÆ Leach 1815 (Ly-cæn'i-dæ, from the Greek *λύκαινα*, a surname of Venus). German, Bläulinge, Feuerfalter. French, Azurés, Papillons Bleus. Blues, Coppers, Hairstreaks, Gossamer-winged Butterflies.

Minute to small butterflies, the upper surfaces of the wings of which are usually metallic blue, green, copper, and bronze in combination with bright or

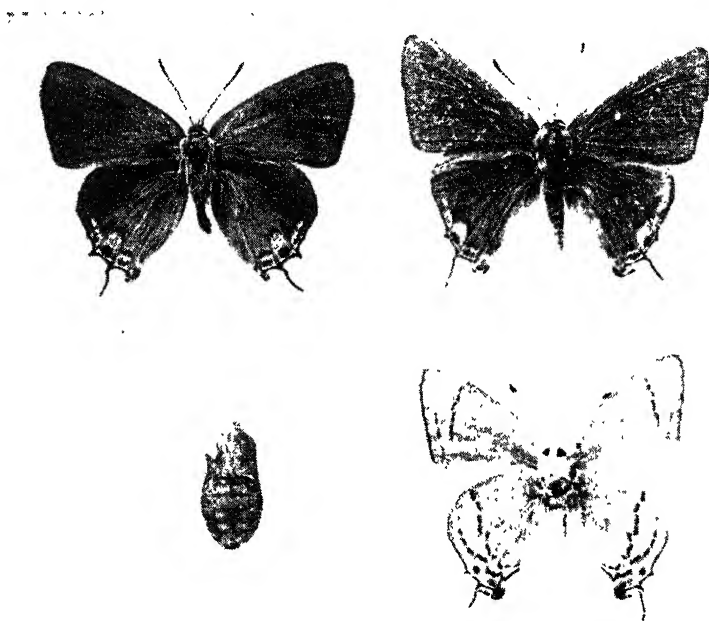


FIG. 173. The bean lycænid, *Strymon melinus* (Hübner). Adults and chrysalis.

dull colors whereas the undersides are dull and cryptic. Eyes smooth or hairy, encircled by a narrow border of white scales. Antennal club straight; segments ringed with white scales. Forelegs of males short; tarsi reduced, one-segmented, with one or both claws absent; those of the female normal and with both claws present. Wings normal or hind pair with tails,¹ anal lobe absent; subcosta

¹ The genera *Strymon* Hübner, *Rapala* Moore, *Lehera* Moore, *Zephyrus* Dalman, *Heliophorus*

without spur or humeral vein at base, first branch of media usually arising at or near apex of discal cell. Sexual dichromatism common, manifested usually in brighter and more strikingly colored males. Eggs reticulated and otherwise sculptured; circular and flattened; laid singly on the host plants. Caterpillars peculiar, short, flattened, chiton-shaped or slug-like; smooth or pollinose; head retractile, legs short and hidden; some secrete fluids sought by ants and a few are strictly myrmecophilous; others are predacious on scale insects and perhaps on other homopterous insects. By far the greater number are phytophagous and are specially found on plants of the family LEGUMINOSÆ. The chrysalids are short, cylindrical, smooth, and rarely humped; attached by the cremaster and usually with a girdle. A few are subterranean. The adults are strong fliers, and many hibernate under very adverse conditions. There are several broods a year.

The smallest North American species, *Brephidium exilis* (Boisduval), has a wing expanse of 18 mm. and is used as whole mounts in jewelry. A smaller species, *Zizula gaika* Tr. of India, has a wing expanse of only 15 mm. One of the largest species is the archaic *Liphyra brassolis* Westwood, 70–75 mm. expanse, which occurs in Indo-Australia. It is orange and black, has the veins R_4 and R_5 of the fore wings separate, and the larvæ live in the nests of and are predacious on the young of the green tree ant, *Æcophylla smaragdina* (Fab.) in Australia (Tillyard, 1926). *Euliphyra mirifica* Holland is associated with the same ant in West Africa. Other predacious species are the wanderer, *Feniseca tarquinius* (Fab.) on the woolly aphid in North America; *Gerydus chinensis* Felder on aphids in China; *Lycæna arion* Fab., in which the first-stage larvæ are phytophagous and the other stages are predacious on ant larvæ, *Myrmica*, in Europe; *Spalgis epius* Westwood on mealybugs in India. The caterpillars of the latter are covered with long white wax filaments and thus somewhat simulate their hosts.

In North America the butterflies are usually arranged into three groups:

(1) THE BLUES; about 40 described species. The spring azure, *Lycæna pseudargiolus* Bdv. and Lec., is one of the commonest and most beautiful and the most widely distributed world species in the family. The eyed blue, *Glaucopsyche xerces* (Bdv.), 33 mm. expanse, and *Plebeius acmon* (Dlb. and Hew.) are common throughout parts of western North America.

(2) THE COPPERS. The American copper, *Lycæna hypophlæas* (Bdv.), is the commonest North American species. The larvæ feed on clover and sorrel. The bronze copper, *L. thæ* (Guérin), is also a widely distributed eastern species whose larvæ feed on curled dock. The fine little *L. epixanthe*, Bdv. and LeConte, breeds in the cranberry bogs of New England. The arota, *Tharsalea arota* (Bdv.), occurs along the Pacific coast, the larvæ feeding on knotweed. *Virachloa isocrates* (Fab.) is a serious pest of pomegranates and guavas in India.

Geyer, *Thecla* Fab. and many others have one tail on each of the hind wings; *Atlides* Hübner, *Chliaria* Moore, and *Aphnæus* Hübner have two; and *Catapacilma* Röber and *Horaga* Moore have three.

(3) THE HAIRSTREAKS. These butterflies are distinguished by one or two thin tails on each of the hind wings. They are usually dark in color. The males have a tuft of hair-like scales or beard on the front. The great purple hairstreak, *Ailides halesus* (Cramer), expanse 30–38 mm., is iridescent purple, blue, or greenish above and with two pairs of tails. The larvæ feed on mistletoe, and the species ranges from tropical North America far north into the temperate areas. The bean lycænid, *Strymon melinus* (Hübner), expanse 25–30 mm., is gray; the larvæ feed on legumes and other unrelated plants, as well as fruits, throughout North America. The banded elfin, *Incisalia niphon* (Hbn.), breeds on pine east of the Rocky Mountains.

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CHAPTER XXXII

29. Order COLEOPTERA Linnæus 1758

(Col'e-op'ter-a, from the Greek *κολεός*, sheath, + *πτερά*, wings; referring to the thickened fore wings or elytra.) German, Käfer. French, Coléoptères.

Beetles, Weevils.

Minute to large insects with leathery or horny integument; complex metamorphosis; strong biting and chewing mouth parts; wings, two pairs, both or hind pair may be absent; elytra or fore wings similar to body in texture, useless in flight, and serving to protect body when folded, usually meeting in a straight line down the dorsum, sometimes shortened, frequently fused; hind wings membranous, with few veins, completely folded beneath elytra at rest; head free, normal or prolonged forwards or downwards into a snout; eyes conspicuous; ocelli usually absent; antennæ variable in size and form, usually 11-segmented; mandibles strong and may be very greatly enlarged; palpi prominent, two- to five-segmented; prothorax distinct, usually free; legs adapted for many purposes; tarsi one- to five-segmented, normally five; abdomen usually 10-segmented, sterna not all visible; cerci absent; genitalia concealed; terminal segments often retractile and forming an ovipositor in the female. Larvæ campodeiform or eruciform. Pupæ exarate or with appendages free.

This is, at the present time, the largest order of insects and comprises about 40 per cent of all the known members of the class INSECTA and no less than 250,000 described species. No group of animals has more successfully occupied the land and more effectively met the diversified requirements of habitat and climate. Aside from the polar caps and the oceans, they are to be found in every corner of the world. Because of their great numbers and varied habitats it is to be expected that beetles and weevils have assumed remarkable variations in structure and habits, which is true, but withal there is a homogeneity in form and structure that makes the order one of the most distinctive and easily recognized among insects. While the great majority live on the land, a number of large families live in fresh water, and many variable species are littoral. A great many species have been widely distributed by commerce.

The members are capable of living upon all kinds of plant and animal life and may be predacious, carnivorous, saprophagous, endoparasitic, or phytophagous. They may live on or in all parts of dead and living plants, on the surface of the ground, in the ground, or in the water. No product of plant or animal origin is exempt from their attacks. Many species also are inquilines in the nests and communities of other insects.

Although man suffers from the destructive and pestiferous habits of many coleopterous insects, others are a source of great delight to him. Who has not thrilled at the sight of fireflies on a warm summer evening? The scarab beetles

have been adored and worshipped throughout the ages in Egypt and in earlier civilizations. The ladybird beetles have been admired and protected throughout most of Europe since earliest days. More naturalists have enthused about beetles than over all other insects, and the history of coleopterology is so extensive as to be almost a history of entomology. No one can view a neatly prepared collection of beetles and weevils without becoming interested in them.

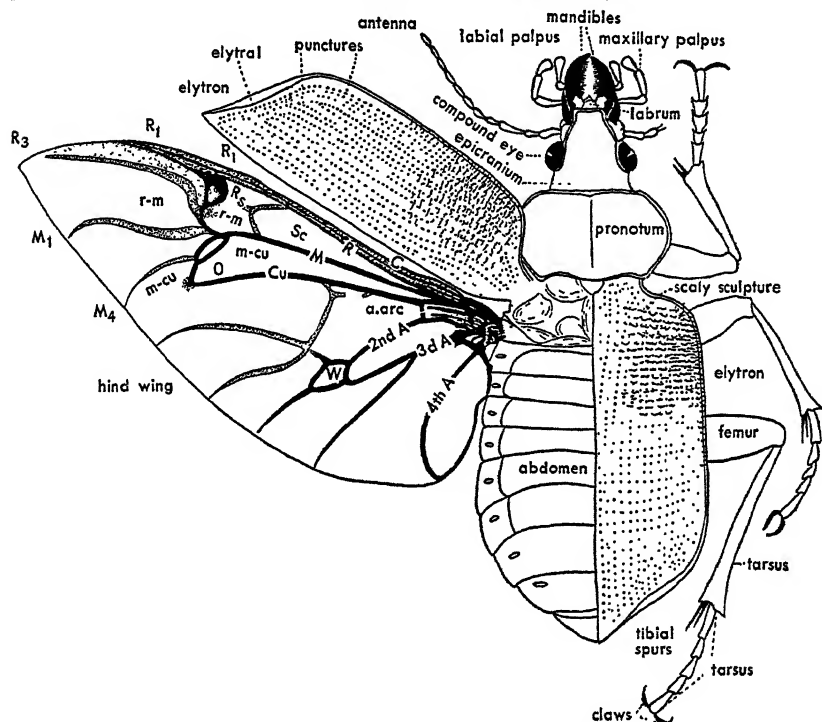


FIG. 174. The common black calosoma, *Calosoma semilaeve* LeConte. Adult with left elytron and wing spread and principal parts named. (From *Insects of Western North America*.)

Not only are they among the most beautiful but they are the most enduring and permanent specimens of life procurable.

The larvæ are as variable in form and habits as the adults and live under similar conditions. They are either generally caraboid and active, living freely and exposed; scarabæoid-fleshy, curved, sluggish, with well-developed legs and living in seclusion and darkness; cerambycoid: fleshy, subcylindrical, straight, and apodous or nearly so; and curculionoid: fleshy, subcylindrical, curved, and apodous. While they usually have three pairs of well-developed legs, many forms, including particularly the weevils, are apodous. Certain species like the blister beetles and seed weevils are active forms when first born and become eruciform after finding and developing in the permanent host.

The larvæ of many species pupate in a cell in the ground, burrow in wood, or other secluded places; while certain leaf weevils spin lace-like cocoons from a sticky quick-drying fluid taken from the anal opening by the mandibles and slowly and skillfully woven. The normal life cycles may be very short, requiring from one to four generations a year, or may be quite long, involving from one to five years for a single complete life history. Rarely from 25 to 30 years have been recorded for certain wood-boring beetles. Hibernation and æstivation may occur in all the various stages.

The fossil record may be summarized as follows:

Order PROCOLEOPTERA Tillyard 1924, from Upper Permian, Belmont, New South Wales. Early ancestors.

Trias, Upper — Ipswich, Australia — Beetles abundant.

Liassic — Europe — abundant.

Jurassic, Upper — Europe — abundant.

Tertiary — North America — abundant.

Eocene — many modern genera occur.

Baltic Amber — nearly 500 species known.

Miocene — Florissant, Colo. — nearly 1,000 species known.

BASIS FOR CLASSIFICATION FOR COLEOPTERA

1. **Character of the Exoskeleton and Elytra:** Whether hard and heavily sclerotized or soft and leather-like; the surface, whether smoothed and polished or pubescent, hairy, scaly, punctured, pitted, rugose, ribbed, or striated; length of elytra, whether covering or only partially covering the abdomen. The wing venation is also used to some extent in separating families.
2. **Antennæ:** The shape of the antennæ is exceedingly variable and may be *setiform* or awl-like and *filiform* or thread-like, in which all segments are more or less alike and gradually diminish in size to a point apically; *moniliform*, or with the segments rounded and bead-like; *serrate*, or with the segments extending laterally on the outside like saw-teeth; *clavate*, in which the segments gradually increase in size apically to form a club; *capitate*, ending in usually three to five large loose or fused segments which form a terminal enlargement or ball-like structure; *geniculate* or elbowed, consisting of a small basal segment and the longest segment forming the scape, followed by a short pedicel and a number of small ring-joints and segments composing the flagellum (these segments are often held at an angle to the scape); *lamellate* geniculate or capitate types, in which the apical portion is composed of a number of lamellæ that fit together like leaves of a book; *pectinate*, where the segments have long lateral slender extensions so as to produce a comb-like appearance and occurring usually in males. The position of the insertion of the antennæ on the head is also important.
3. **Abdominal Sternites:** In these closely joined insects there is a fusion of segments at the base and apex of the abdomen with the result that the

first sternite is always absent although the first tergite is present and the second sternite is absent or fused with the third in many of the POLYPHAGA. The ninth and 10th sternites are missing. Thus when viewed from the venter a variable number of sternites may be discernible. The number of visible tergites may also be important in classification.

4. **Coxæ and Coxal Cavities:** The shape and position of the coxæ and the coxal cavities play an important rôle in separating the families and genera.

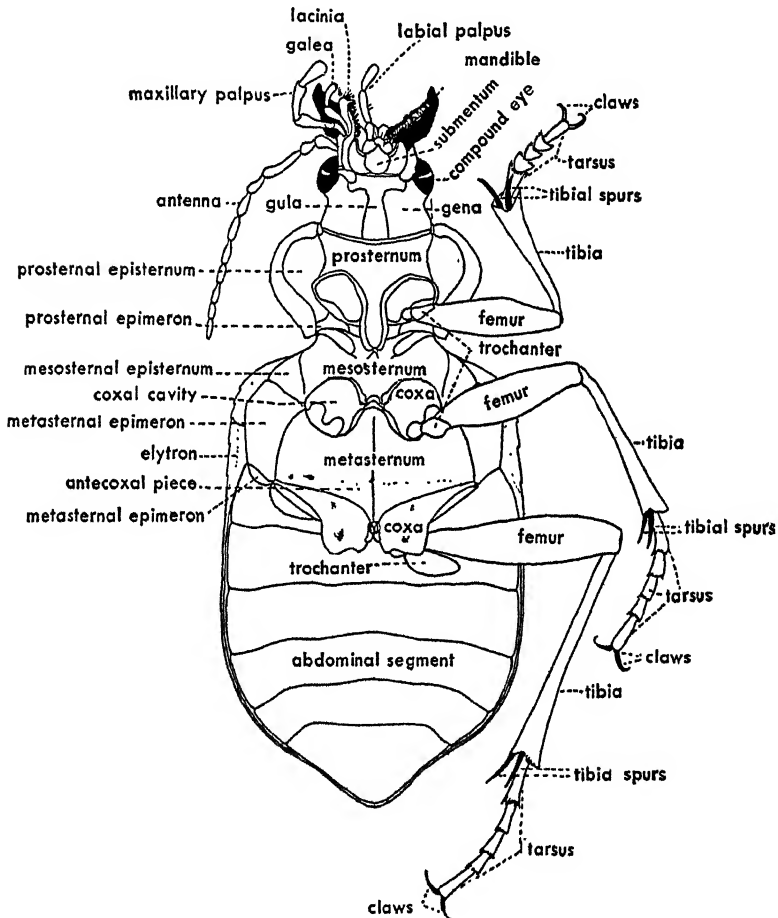


FIG. 175. The common black calosoma showing ventral side with principal parts indicated. (From *Insects of Western North America*.)

The coxæ may be globular, cone-shaped, elongate, egg-shaped, narrow or broad; contiguous, approximated, or far apart; transversely or obliquely situated; coxæ of hind legs flat and immovably incorporated into the

thorax. The coxal cavities assume the shape of the base of the coxæ which fit into them. They are said to be open when they form the margin of the thoracic segments. In all the ADEPHAGA, excepting the family CUPE-SIDÆ, they extend across and divide the first abdominal segment and are said to be open behind. The presence of a trochantin, on the outer or basal part of the divided trochanter, is also used.

5. **Tarsal Segments:** Normally the members of this order have five-segmented tarsi. The segments may be similar or variable in size and shape. In certain groups the first segment is very small and inconspicuous while in others the fourth is so small as to be hidden and therefore easily overlooked. Frequently a number of segments may be greatly widened and pad-like, a condition commonly found in the fore tarsi of males. The last segment is usually long and somewhat slender but may even be the largest. The tarsal formulæ, beginning with the anterior legs, may be constituted as follows; 5-5-5 (five in each of the three pairs of legs, or pentamerous); 5-5-4 (heteromerous); 4-4-4 (tetramerous); 3-3-3 (trimerous).

SUMMARY OF IMPORTANT ADULT CHARACTERS — EXTERNAL ANATOMY

Size¹ — minute (0.25 mm.) to large (150 mm. long).

Shape — variable, elongate-oval, slender and robust, cylindrical, flattened, or even larviform in some females.

Exoskeleton — usually hard, or leathery and elastic; smooth and shiny or dull and clothed with hairs, scales, or spines; variously sculptured, striated, and punctured; and ornamented with chitinous horns, tubercles, and other out-growths.

Coloration — forms occurring in temperate and cold regions usually black, brown, yellowish, or reddish — a few metallic and brightly colored forms present. Bright colors are associated with diurnal habits (cicindelids, buprestids, chrysomelids, clerids, flower-loving cerambycids, etc.) Tropical forms may be brilliantly colored, many being metallic and others enameled. They are among the most beautiful objects in nature. Portions of the bodies have been used in the arts as jewels in all parts of the world.

Head — prognathous and hypognathous; free; rarely with a basal constriction or neck; normal or prolonged into a snout in the weevils.

Eyes — large, well developed, round, elongated, irregular, or rarely divided; finely or coarsely faceted; variously placed on the head; absent in certain cave-dwelling species and ectoparasites.

Ocelli — usually absent; a single frontal ocellus or a pair among the STAPHYLINIDÆ and DERMESTIDÆ. Usually present in the larvæ.

Antennæ — exceedingly variable in size and shape; normally 10- or 11-seg-

¹ The smallest species are to be found in the family TRICHOPTERYGIDÆ or fungus beetles which vary from 0.25-2 mm. in length, whereas the largest and bulkiest beetles are the South American giants in the families CETONIIDÆ and DYNASTIDÆ which may attain a length of 150 mm. to the end of the horn.

mented but the number may vary from one or two to six or even 27 segments in rare cases; remarkably developed in males; free or resting in grooves in the prosternum; setiform, filiform, moniliform, clavate, capitate, serrate, flabellate, geniculate, and lamellate.

Mouth parts — typically biting, the primitive type; many forms feed only on liquids. *Clypeus* — divided or reduced; *labrum* — variable; absent in weevils. *Mandibles* — hard, strong for biting and chewing, crushing; and piercing and sucking; may be enormously developed in the stag beetles and longicorns; usually move horizontally, but act vertically in certain weevils. *Maxillæ* — large, usually bilobed or toothed. *Galea* — may be two-segmented and palpiform. *Maxillary palpi* — three- to five-segmented (normally four-segmented); greatly developed in a few families. *Labium* — entire or rarely divided. *Mentum* — conspicuous. *Submentum* — distinct or fused with gula. *Gula* — well developed in many. *Ligula* — variable; entire or lobed. *Labial palpi* — one-, two-, or three-segmented (normally three-segmented).

Thorax — Well developed and divided by many distinct sutures.

Prothorax — distinct, usually free, narrower than or as wide as the mesothorax; pronotum a single sclerite.

Meso- and metathorax — large, closely fused and separated into definite sclerites by distinct sutures.

Legs — variable, usually strong and frequently long and slender; modified for walking, running, jumping (enlarged hind femora), digging (fossorial forelegs), and swimming (hairs and spines on middle and hind legs). *Coxæ* — large, plate-like, conical, or globular; simple or laminate; contiguous or variously separated; cavities open or closed behind; shape and position important in classification. *Trochanters* — single or double, with basal part, or *trochantin*, attached to first two pairs of coxæ in certain species. *Femora* — may be enlarged for jumping. *Tibiæ* — modified for many uses; rounded or flat and toothed; spurs usually present; swimming hairs present in aquatic forms. *Tarsi* — one- to five-segmented, normally five, but may be heteromorous (5-5-4); segments I and IV often minute, sometimes absent; segments round or pad-like, smooth or hairy. *Claws* — simple or complicated (pectinate or cleft); single or paired.

Wings — remarkable because of the hard or leathery fore pair or elytra which are useless in flight but afford protection to the body. *Elytra* — long and covering abdomen or brachypterous; smooth, polished, granular, striated, punctate, scaly, or hairy; sometimes fused and uniting in a line down middle of dorsum or separated posteriorly. *Hind wings* — one pair: present, atrophied, or absent; large; membraneous, with few veins; usually folding longitudinally and transversely.

Spiracles — one pair between prothorax and mesothorax and one pair on the metathorax.

Abdomen — normally 10-segmented; segment I atrophied; sternites 3 to 9 visible; terminal segments or pygidium constricted, elongated and retractile

and may function as an ovipositor. Male genitalia — concealed within the abdomen and exerted between sternites 9 and 10.

Sexual dimorphism — well developed in many species and characterized by marked differences in size, color, and external anatomical characteristics. Some of the latter may be summarized as follows:

Male

1. Large horn-like mandibles.
2. Greatly developed antennæ
 - a. Pectinate
 - b. Lamellate.
3. Fore tarsi enlarged, certain aquatic forms with suckers.
4. Longer legs.

Female

1. Often larger size.
2. Reduced antennæ.
3. Enlarged tibiæ in fossorial forms.
4. Change in form
 - a. Larviform
 - b. Disk-like
 - c. Trilobite.

SUMMARY OF IMPORTANT ADULT CHARACTERS — INTERNAL ANATOMY

These characters are far too complicated and varied to permit more than the simplest statements.

Digestive System.

Mouth — well developed in herbivores and little more than a receptacle to receive the liquids at the bases of the mandibles in predacious forms.

Pharynx — the seat of the organs of taste in the epipharynx.

Œsophagus — simple tube of variable size.

Crop — enlargement of the posterior portion of the Œsophagus; absent in some genera and very large in others.

Proventriculus or gizzard — small chamber with chitinized or horny ridges and teeth fully developed, particularly in the predators and wood eaters — not so pronounced in the others.

Mid-intestine — tubular, long to short; sac-like; convoluted, coiled, with *gastric cæca* present — sometimes in series.

Hind intestine — short to long, small or large, usually convoluted, with or without *cæca*. *Colon* or bladder-like *cæcum* may be present in certain genera.

Rectal papillæ — rarely present.

Malpighian tubes — four to six.

Salivary glands — absent or present.

Silk glands — present in CHRYSOMELIDÆ, CURCULIONIDÆ, and other families; fluid secreted by Malpighian tubes and taken from the anus with the mouth. Used in making cocoons.

Rectal glands — paired organs opening near the anus; secreting odorous, fetid, and offensive fluids used in self defense; sometimes expelled with explosive force.

Circulatory System.

Dorsal vessel with variable number of chambers. Aorta extends through thorax into the head and is branched at apex.

Respiratory System.

Tracheal system well developed in terrestrial and aquatic forms.

Trunks large — usually two extending along each side. Air sacs small and numerous in all parts of the body and highly developed in certain of the scarabæoid groups.

Spiracles with double openings and biforous type may also occur in larvæ of the elaters.

Thoracic spiracles — two pairs.

Abdominal spiracles — five, seven, eight, or 10 pairs.

Nervous System.

Supra- and infra-oesophageal centers either fused or separated.

Ganglia — three thoracic; seven or eight abdominal. Number may vary from two, three, four, five, six, to seven. Head and thoracic ganglia may be merged together. Organs of smell and hearing located on the antennæ.

Reproductive System.

Quite variable within the order.

Male — *Testes* — simple, coiled tubes in the carnivorous forms; complex and divided into follicles in the phytophagous forms.

Accessory glands — variable; *ejaculatory duct* — present; *vesicula seminalis* — present; *claspers* — wanting.

Female — *Ovarioles* — polytrophic in carnivorous species and acrotrophic in the phytophagous and general feeders. Number varies from two to 12 or more in each ovary. *Colleterial glands* — may be present in connection with each oviduct; *spermatheca* — present and opening direct into the vagina or the *bursa copulatrix*; *accessory glands* occur in connection with the spermatheca; *fecundation canal*, or passage from spermatheca to the eggs, present; *bursa copulatrix*, or storage sac supplying the spermatheca, also present.

SUMMARY OF IMPORTANT LARVAL CHARACTERS

Size — minute to very large — usually larger or longer than the adults.

Shape — exceedingly varied; two common generalized types:

(1) caraboid or campodeiform — elongated and flattened and with well-developed legs, antennæ, and other appendages; active and usually free living.

(2) scarabæoid or eruciform — robust, rounded, elongated, or short and stout; often crescent-shaped; legs well developed or wholly absent; usually sluggish and concealed.

Integument — usually tough and armor-like in caraboid type and thin and delicate in scarabæoid type; smooth, shining, rough, wrinkled, hairy, or spined.

Coloration — dull or cryptic, rarely brilliant and metallic in the caraboid type and transparent, whitish, or pale yellow in the scarabæoid type.

Head — well developed, prominent, hard, free; usually shining and pigmented; prognathous or hypognathous.

Eyes — simple or ocelli, one to six pairs arranged singly or in groups on each side of the head; wholly absent or mere eyespots.

Antennæ — short, variable number of segments; long or vestigial.

Mouth parts — similar to those in adults; often greatly reduced.

Mandibles — may be long and sickle-like and modified for grasping and sucking the prey in many aquatic forms.

Gula — rudimentary or well developed. *Superlinguæ* pronounced or reduced. *Maxillæ* — prominent, palpi papillate or long, one- to five-segmented. *Mala* — one- to two-segmented, present in most forms.

Labium — without paraglossæ, palpi normally two-segmented (one-segmented in CURCULIONIDÆ).

Thorax — closely fused in most scarabæoid types; distinct and free in active caraboid forms.

Legs — three thoracic pairs present with tarsi and paired claws in carnivorous forms; tarsi fused with tibix and claws single in most herbivorous types; short and abortive or long and normally segmented in free-living, active forms; adapted for swimming in aquatic groups; present in first stages and absent in later stages of LARIIDÆ and MELOIDÆ; and abortive or wholly absent in the CERAMBYCIDÆ, ELATERIDÆ, CURCULIONIDÆ, SCOLYTIDÆ, and other families.

Spiracles — with single or double openings; one pair between pro- and mesothorax and one pair on the metathorax in LYCIDÆ.

Abdomen — distinctly nine- or 10-segmented. Anal segment often used as a sucker or a pseudopod and may have chitinized, fixed or mobile, simple or segmented processes or urogomphi on the dorsum.

Spiracles — usually one pair on each segment I to VIII inclusive.

Cerci — often present in free-living, active forms; simple or segmented, fixed or mobile.

THE FAMILIES OF COLEOPTERA

A. Suborder ADEPHAGA Emery 1885

I. Superfamily CARABOIDEA Leng 1920

1. Family CICINDELIDÆ
2. " CARABIDÆ
3. " AMPHIZOIDÆ
4. " OMOPHRONIDÆ

5. Family HYGROBIIDÆ
6. " HALIPLIDÆ
7. " DYTISCIDÆ

II. Superfamily GYRINOIDEA Leng 1920

8. Family GYRINIDÆ

III. Superfamily PAUSSOIDEA Tillyard 1926

9. Family PAUSSIDÆ

B. Suborder POLYPHAGA Emery 1885

IV. Superfamily HYDROPHILOIDEA Leng 1920 (PALPICORNIA)

10. Family HYDROPHILIDÆ

- V. Superfamily STAPHYLINOIDEA Ganglbauer 1895
- | | |
|------------------------------|----------------------|
| 11. Family BRATHINIDÆ | 20. Family LEPTINIDÆ |
| 12. " SILPHIDÆ | 21. " HYDROSCAPHIDÆ |
| 13. " LEIODIDÆ (LIODIDÆ) | 22. " PTILIIDÆ |
| 14. " CLAMBIDÆ | 23. " SCAPHIDIIDÆ |
| 15. " SCYDMÆNIDÆ | 24. " STAPHYLINIDÆ |
| 16. " ORTHOPERIDÆ | 25. " PSELAPHIDÆ |
| 17. " PHÆNOCEPHALIDÆ | 26. " CLAVIGERIDÆ |
| 18. " DISCOLOMIDÆ | 27. " GNOSTIDÆ |
| 19. " PLATYPSYLLIDÆ | 28. " NIPONIIDÆ |
| 29. " SPHÆRITIDÆ (SPHÆRIIDÆ) | |
| 30. " HISTERIDÆ | |
- VI. Superfamily CANTHAROIDEA Reitter 1906 (DIVERSICORNIA, MALA-CODERMATA, CANTHARIDIFORMIA)
- | | |
|-----------------------|-----------------------|
| 31. Family LYCIDÆ | 37. Family MALACHIIDÆ |
| 32. " LAMPYRIDÆ | 38. " MELYRIDÆ |
| 33. " PHENGODIDÆ | 39. " RHADALIDÆ |
| 34. " CANTHARIDÆ | 40. " DASYTIDÆ |
| (TELEPHORIDÆ) | 41. " CLERIDÆ |
| 35. " RHAGOPHTHALMIDÆ | 42. " CORYNETIDÆ |
| 36. " DRILIDÆ | 43. " OTHNIIDÆ |
- VII. Superfamily LYMEXYLOIDEA Leng 1920
- | | |
|-----------------------|------------------------|
| 44. Family LYMEXYLIDÆ | 46. Family TELEGEUSIDÆ |
| 45. " MICROMALTHIDÆ | |
- VIII. Superfamily CUPESOIDEA Leng 1920
47. Family CUPESIDÆ (CUPIDÆ, CUPEDIDÆ)
- IX. Superfamily ELATEROIDEA Leng 1920 (STERNOXIA)
- | | |
|------------------------|------------------------|
| 48. Family RHIPICERIDÆ | 53. Family CEROPHYTIDÆ |
| 49. " PLASTOCERIDÆ | 54. " EUCNEMIDÆ |
| 50. " CEBRIONIDÆ | (MELASIDÆ) |
| 51. " PHYLOCERIDÆ | 55. " THROSCIDÆ |
| 52. " ELATERIDÆ | 56. " BUPRESTIDÆ |
- X. Superfamily DRYOPOIDEA Leng 1920 (MACRODACTYLI)
- | | |
|--------------------------|-----------------------|
| 57. Family PSEPHENIDÆ | 61. Family GEORYSSIDÆ |
| 58. " DRYOPIDÆ (PARNIDÆ) | 62. " HELMIDÆ |
| 59. " CYATHOCERIDÆ | 63. " HETEROCERIDÆ |
| 60. " LIMNICHIDÆ | |
- XI. Superfamily DASCILLOIDEA Reitter 1906 (FOSSIPEDES)
- | | |
|-----------------------|-----------------------|
| 64. Family DASCILLIDÆ | 68. Family DERMESTIDÆ |
| 65. " HELODIDÆ | 69. " BYTURIDÆ |
| 66. " EUCINETIDÆ | 70. " NOSODENDRIDÆ |
| 67. " CHELONARIIDÆ | 71. " BYRRHIDÆ |
- XII. Superfamily RHYSODOIDEA Leng 1920
72. Family RHYSODIDÆ

XIII. Superfamily CUCUJOIDEA Sharp 1912 (CLAVICORNIA)

- | | |
|-----------------------------|--------------------------|
| 73. Family SYNTHELIIDÆ | 83. Family CRYPTOPHAGIDÆ |
| 74. " OSTOMATIDÆ | 84. " PHALACRIDÆ |
| (OSTOMIDÆ, | 85. " CATOPOCHROTIDÆ |
| TEMNOCHILIDÆ, | 86. " THORICTIDÆ |
| TROGOSITIDÆ) | 87. " MONÆDIDÆ |
| 75. " NITIDULIDÆ | 88. " COSSYPHODIDÆ |
| 76. " MONOTOMIDÆ | 89. " LATHRIDIIDÆ |
| 77. " RHIZOPHAGIDÆ | 90. " MYCETÆIDÆ |
| 78. " CUCUJIDÆ | 91. " MYCETOPHAGIDÆ |
| 79. " SILVANIDÆ | 92. " COLYDIIDÆ |
| 80. " HELODIDÆ (see p. 527) | 93. " MURMIDIIDÆ |
| 81. " EROTYLIDÆ | 94. " ENDOMYCHIDÆ |
| 82. " DERODONTIDÆ | 95. " COCCINELLIDÆ |

XIV. Superfamily MORDELLOIDEA Leng 1920

- | | |
|-----------------------|-------------------------|
| 96. Family CEPHALOIDÆ | 103. Family PYROCHROIDÆ |
| 97. " EDEMERIDÆ | 104. " PEDILIDÆ |
| 98. " MORDELLIDÆ | 105. " ADERIDÆ |
| 99. " RHIPPHORIDÆ | 106. " ANTHICIDÆ |
| 100. " MELOIDÆ | 107. " EUGLENIDÆ |
| 101. " PYTHIDÆ | 108. " SCRAPTIIDÆ |
| 102. " EURYSTETHIDÆ | 109. " SERROPALPIDÆ |

XV. Superfamily TENEBRIONOIDEA Seminov 1902

- | | |
|-------------------------|-----------------------|
| 110. Family ALLECULIDÆ | 115. " ASPIDIPHORIDÆ |
| 111. " TENEBRIONIDÆ | 116. " SPHINDIDÆ |
| 112. " LAGRIIDÆ | 117. " ECTREPHIDÆ |
| 113. " MONOMMATIDÆ | 118. " CIIDÆ (CISIDÆ, |
| (MONOMMIDÆ) | CIOIDÆ) |
| 114. Family MELANDRYIDÆ | |

XVI. Superfamily PTINOIDEA Leunis 1860

- | | |
|---------------------|----------------------|
| 119. Family LYCTIDÆ | 121. Family ANOBIIDÆ |
| 120. " BOSTRICHIDÆ | 122. " PTINIDÆ |

XVII. Superfamily SCARABÆOIDEA Bedel 1911

- | | |
|------------------------|----------------------|
| 123. Family SCARABÆIDÆ | 134. Family RUTELIDÆ |
| 124. " ÆGIALIIDÆ | 135. " DYNASTIDÆ |
| 125. " APHODIIDÆ | 136. " CETONIIDÆ |
| 126. " OCHODÆIDÆ | 137. " TRICHIIDÆ |
| 127. " HYBOSORIDÆ | 138. " ORPHNIDÆ |
| 128. " GEOTRUPIDÆ | 139. " EUCHIRIDÆ |
| 129. " PLEOCOMIDÆ | 140. " PACHYPODIDÆ |
| 130. " GLAPHYRIDÆ | 141. " PHÆNOMERIDÆ |
| 131. " ACANTHOCERIDÆ | 142. " PASSALIDÆ |
| 132. " TROGIDÆ | 143. " LUCANIDÆ |
| 133. " MELOLONTHIDÆ | (SINODENDRIDÆ) |

XVIII. Superfamily CERAMBYCOIDEA Leng 1920 (PHYTOPHAGA)

- | | |
|-------------------------|--------------------------------|
| 144. Family CERAMBYCIDÆ | 146. Family LARIIDÆ (BRUCHIDÆ, |
| 145. " CHRYSOMELIDÆ | MYLABRIDÆ) |

C. Suborder RHYNCHOPHORA

XIX. Superfamily BRENTOIDÆ Pierce 1916

147. Family BRENTIDÆ (BRENTIDÆ)

XX. Superfamily CURCULIONOIDEA Hopkins 1911

148. Family ANTHRIBIDÆ

151. Family PROTERRHINIDÆ

(PLATYSTOMIDÆ)

152. " CURCULIONIDÆ

149. " BELIDÆ

153. " PLATYPODIDÆ

150. " AGLYCYDERIDÆ

154. " SCOLYTIDÆ

(IPIDÆ)

KEY TO SUBORDERS¹

1. Head not prolonged into a beak; gular sutures double, at least anteriorly and posteriorly; prosternal sutures distinct 2
Head usually prolonged into a beak; gular sutures fused or lacking; prosternal sutures lacking. Vegetable feeders . . . RHYNCHOPHORA p. 598
2. Outer lobe or galea of maxillæ palpiform; first visible abdominal sternite divided by the hind coxal cavities; hind wings with one or two cross veins near the middle; pleural sutures of prothorax present; antennæ filiform or nearly so; tarsi five-segmented; larvæ thysanuriform, the tarsi with one or two claws. Largely predacious or carnivorous ADEPHAGA
Outer lobe or galea of maxillæ not palpiform; first visible abdominal sternite not usually interrupted by the hind coxal cavities; hind wings without cross veins; pleural sutures of prothorax absent; antennæ and tarsi variable; larvæ variable, the tarsi and claws fused. Animal and vegetable feeders POLYPHAGA p. 542

A. Suborder ADEPHAGA Emery 1885

KEY TO SUPERFAMILIES

1. Abdomen with six or more visible sternites; antennæ filiform . . . 2
Abdomen with four visible sternites; antennæ greatly thickened apically, clavate or broadly laminate. Myrmecophilous . . . PAUSSOIDEA
2. Eyes entire, not divided; antennæ elongate, slender. Predacious . . . CARABOIDEA
Eyes divided, appearing as two pairs; antennæ very short, robust, irregular GYRINOIDEA p. 539

I. Superfamily CARABOIDEA Leng 1920

KEY TO MORE IMPORTANT FAMILIES

1. Metasternum with a distinct transverse suture demarking a triangular antecoxal sclerite; posterior legs without dense fringes of long hair . . 2
Metasternum without a transverse suture or antecoxal sclerite; posterior legs with dense fringes of long hair. (Predacious Diving Beetles.) . . . DYTISCIDÆ p. 537

¹ The writer is indebted to Dr. E. Gorton Linsley for the keys to the COLEOPTERA.

2. Transverse suture in front of hind coxæ extending across the metasternum which is continued behind in a triangular process between the hind coxæ 3
 Transverse suture in front of hind coxæ very short, reaching only across the central portion; metasternum not prolonged between the hind coxæ; front coxæ globular: tibiæ and tarsi without swimming hairs; small dull aquatic or semiaquatic beetles. Rare. **AMPHIZOIDÆ** p. 537
3. Hind coxæ normal; antennæ 11-segmented, with at least the six apical segments pubescent; terrestrial 4
 Hind coxæ fixed and extended into two broad plates covering the femora and the base of the abdomen; antennæ 10-segmented, without pubescence; hind legs without fringe of long hairs for swimming; aquatic. Small, oval, usually dark, water beetles . . . **HALIPLIDÆ** p. 537
4. Clypeus extending on each side beyond the base of the antennæ; antennæ inserted on the front above the base of the mandibles; inner lobe of lacinia terminating in a movable hook; eyes large; head vertical, wider than thorax. Usually medium-sized, slender, brightly colored or metallic blue and green beetles with yellow marks. They occur in damp places and along waterways. Very alert and active. (Tiger Beetles.) **CICINDELIDÆ**
 Clypeus not extending beyond the base of the antennæ; antennæ arising from the sides of the head between the base of the mandibles and the eyes; inner lobe or lacinia of maxillæ not terminating in a movable hook; eyes normal; head horizontal or slightly inclined, usually narrower than thorax. Small to large, usually black, but may be brightly colored and metallic reddish, blue, and green. Fast running. (Predacious Ground Beetles.) **CARABIDÆ** p. 533

Family CICINDELIDÆ Leach 1815, 1817 (Cic'in-del'i-dæ, from the Latin *cicindela*, a glowworm; which has no particular application to these insects). German, Sandkäfer. Tiger Beetles.

Medium-sized, elongated and usually slender, somewhat flattened or nearly cylindrical land beetles, which are characterized by their swift movements, long, dentate, curved mandibles, and long slender legs. The integument is parchment-like or hard and usually smooth, punctate, or somewhat hairy ventrally; somber-colored or mostly brilliant metallic green, blue, red, yellow, and rainbow hues with stripes, spots, and many combinations of colors. Head prognathous, large, free. Antennæ inserted above the bases of the mandibles, simple, filiform, 11-segmented. Eyes prominent. Mouth parts well developed. Clypeus extending laterally over the bases of the antennæ. Mandibles large and formidable. Galea two-segmented. Lacinia terminating in a movable segment or hook. Prothorax free, usually no wider than the head, with epimera and episterna distinct. Wings usually well developed and permitting very rapid flight; absent in *Omus* and other genera. Elytra often beautifully colored, usually completely covering the body or exposing the prolonged tip of the abdomen; fused along the median line in *Omus*. Legs long and slender. Tibial spurs present. Tarsi five-segmented. Claws paired. The abdomen is often

prolonged apically as an ovipositor; with six visible sternites in the female and seven in the male.

Larvæ caraboid, cylindrical; pale or dusky in color; distinctly segmented; with large circular disk-like head, a pair of ocelli, and strong mouth parts;

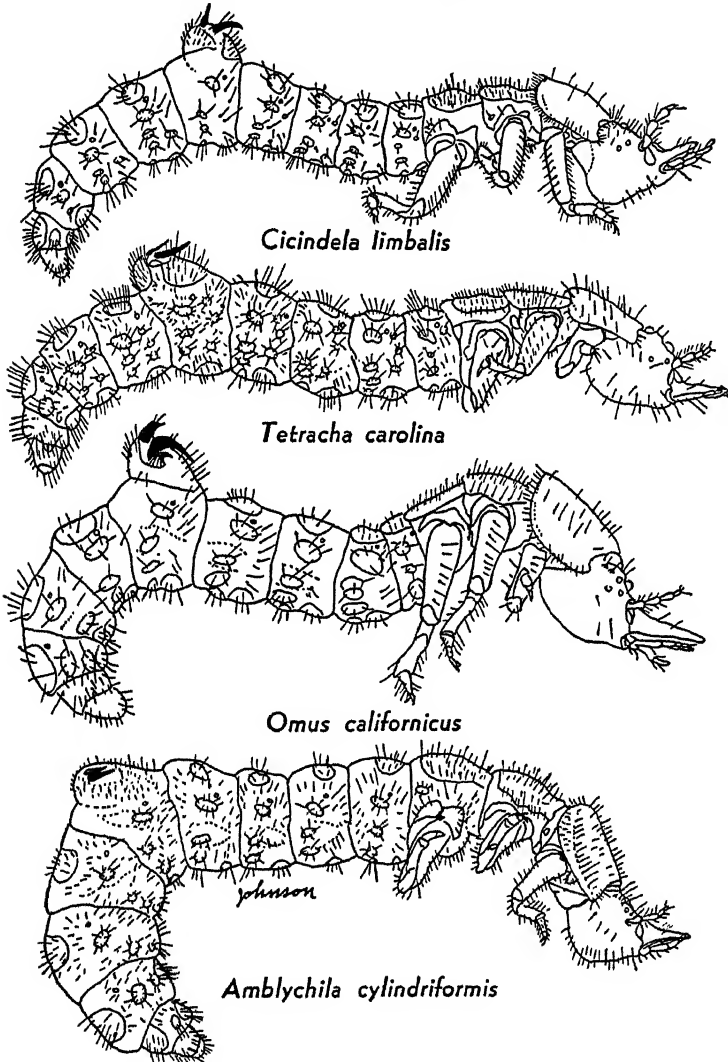


FIG. 176. Larvæ of tiger beetles, CICINDELIDÆ. (Redrawn from Hamilton, 1925.)

abdominal segment V with large characteristic dorsal hooked tubercle or prop for anchorage in the burrows. The larvæ live in vertical or slanting, cylindrical

holes in the ground in which they move up and down rapidly. The disk-like head just closes the burrow entrance. Here they lie in wait for any living prey which they are able to overcome. The larvæ occupy the habitat of the adult along the sandy banks of rivers and bodies of water, in wet meadows, and in damp partially shaded canyons. Certain tropical species utilize the limbs of trees and stems of smaller woody plants for burrows and capture the insects that pass. A few are termitophilous. From 2 to 3 years are required to complete a life cycle. Pupation occurs in the burrows. In New Zealand they are

called "penny doctors" (Tillyard, 1926). Larvæ and adults hibernate.

The adults are mostly active on bright sunny days, but some species are nocturnal. Diurnal forms are exceedingly quick and are among the most difficult insects to capture with a net.

The eggs are deposited in the soil or wherever the burrow is to be constructed.

The members of this family are among the most specialized insects and while they are usually given family rank some systematists place them in a subfamily of the CARABIDÆ. The family is relatively small and consists of but 2,000 species, which are world-wide in distribution. It reaches its greatest development in the tropics where the most brilliant species occur.

Among the interesting apterous species are those of the genus *Omus* Eschscholtz, 32 spp. and subspecies, black, nocturnal hunters which occur only in the hills and mountains of western North America. The genus *Manticora* Fab., of Africa, is composed

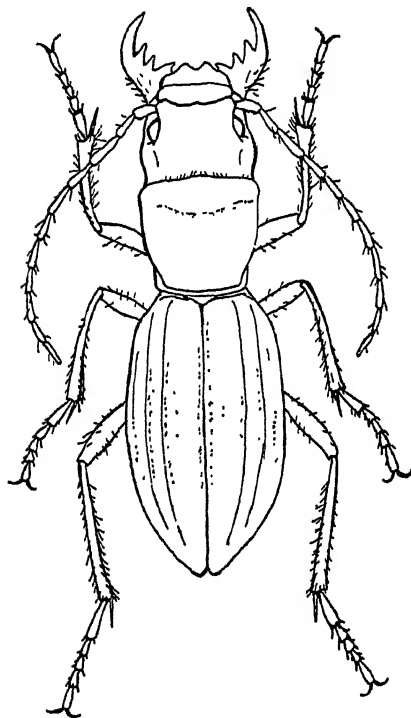


FIG. 177. *Amblycheila cylindriciformis* Say, one of the largest and most remarkable North American tiger beetles. (Drawing by Carl Fuchs.)

of five large apterous, dark species with almost globular bodies and great toothed mandibles. *M. congoensis* Peringuey is from 38–44 mm. long. *Amblycheila cylindriciformis* Say, a large cylindrical species, black with reddish-brown elytra and up to 40 mm. long, occurs in Kansas, Colorado, and New Mexico. Two other species, *A. baroni* Rivers and *A. schwarzi* W. Horn, are much smaller and inhabit Arizona and the latter Utah also. One of the smallest species is *Prothyma leptalis* Bates of Mexico which is but 6 mm. long.

Members of the arboreal genera *Collyris* Fab. and *Tricondyla* Latr. are

small, slender, almost ant-like, and vary in size from 9–28 mm., are metallic green or reddish in color, and are apterous or winged. *Collyris* occurs in Indo-Malaysia and Africa. *C. emarginata* Dejean inhabits cocoa, coffee, cotton, tea, and other plants in Malaysia. *Tricondyla aptera* Olivier, 25 mm., is Indo-Australian. *T. cyanea* Dejean, blue with red legs and 22 mm. long, lives on coffee plants in the East Indies.

The genus *Cicindela* Linn. is the largest genus and is cosmopolitan in distribution. There are about 80 species in North America north of Mexico. *C. brunet* Gory of Malaysia and *C. argentata* Fab., *C. cyanitarsis* Kollar of South America are said to be termitophilous (W. Horn 1915). The genus *Megacephala* Latr. is common throughout the tropics and ranges into the warmer temperate regions. *M. carolina* (Linn.) (*Tetracha* Hope), 18–20 mm. with metallic rainbow colors, is one of the finest species in southern United States and tropical America.

Family CARABIDÆ Leach 1815, 1817 (Ca-rab'i-dæ, from the Greek *κάραβος*, a horned beetle, the stag beetle; referring to the large mandibles). German, Laufkäfer. French, Carabiques. Predacious Ground Beetles, Carabid Beetles.

Minute to large, hard and heavily armored, elongated and flattened, usually smooth, punctate, rugose, or striated, swift-running ground beetles which are either somber-colored, black, brown, yellowish, and reddish, or brilliant metallic blue, green, bronze, and gold with rainbow reflections. All species are practically devoid of hairs and scales. Head free, prognathous, prominent, narrower than thorax, sometimes greatly prolonged. Antennæ long, setiform or filiform, 11-segmented, usually all but basal segments pubescent. Eyes prominent or absent in cave dwellers. Mouth parts well developed. Clypeus not extending beyond base of the antennæ; mandibles large; strong, toothed; maxillæ large; galea usually two-segmented; lacinia without immovable apical hook; palpi five-segmented prominent; mentum small, deeply emarginate; labial palpi large, three-segmented. Apical segments of palpi in male may be greatly enlarged. Prothorax prominent, much narrower than or as wide as the rest of the body, variously shaped. Metasternum with distinct transverse and oblique sutures. Legs long, slender, cursorial. Coxæ variable in shape and position; fore and middle pairs open or closed behind. Tibial spurs present; minute, small, long; terminal or nearly so. Tarsi five-segmented; segments elongate or pad-like, may be greatly enlarged in forelegs of males. Claws simple or pectinate. Elytra entire or truncate; smooth, punctured, rugose, striated, or otherwise sculptured. Wings present and well developed, atrophied, or absent. Abdomen with six visible sternites. Larvæ typical caraboid type, elongated, distinctly segmented, wholly or partly armored dorsally. Head large and strong, with six ocelli on each side and four-segmented antennæ. Legs short, tarsi one- to two-segmented. Abdominal segment IX with a pair of cerci and an anal tube.

The members of this remarkable family live largely on the ground, although a considerable number are more or less arboreal and readily climb trees in

search of prey. Practically all forms are carnivorous and are typically hunters and largely nocturnal in habits. Some forms are diurnal, and many species are attracted to lights. They are to be found in almost every conceivable place but are particularly abundant in forests, along streams and near water, under stones, debris, and other objects on the ground and wherever other small animals are to be found. They are voracious feeders on worms, snails, caterpillars, grubs, maggots, and, in fact, almost any living animal that they can

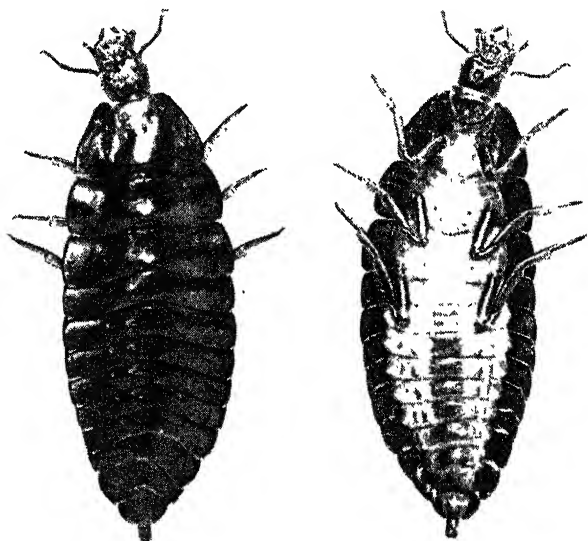


FIG. 178. Larvæ of the snail-eating carabid, *Brennus ventricosus* (Dejean), showing dorsal and ventral aspects.

overcome. In addition to running and climbing, many species are equipped for digging and burrowing in the soil.

Because of their predatory habits and especially because of their destruction of many noxious snails, slugs, and insects, they are considered highly beneficial. A number of genera, however, are harmful in that the members devour berries, seeds, tender shoots, and pollen and foliage of plants, but such depredations are of little import compared with the good they do at other seasons of the year.

The adults of many species have anal repugnatorial glands and are decidedly malodorous. The offensive, volatile secretions are exuded in gaseous or liquid form and in some species expelled in explosive puffs of vapor which can be seen and distinctly heard.

The eggs are usually laid in the ground, and the larvæ remain hidden in the soil, in the grass, under debris and stones or dead bark and wherever they may

find food, protection, and darkness. At night they may travel about freely. Pupation normally occurs in a cell in the ground. Development is quite slow, but there may be from one to two generations a year. Hibernation may take place in almost any stage but chiefly in the larval and adult.

This family is very large, comprising no less than 21,000 described species which represent a wide variety of forms, colors, and habits. There is probably no group of insects that is so widely distributed, being represented from the ice fields of the polar regions to the equator. It reaches perhaps its greatest development in numbers in the temperate regions and in size and color in the tropics.

The size varies from such minute forms as the tiny, blind, ant-like Australian *Illaphanus stephensi* MacLeay, 1 mm. long; the European *Perileptus areolatus* Creutz, 1.5–2.5 mm.; and the North American *Tachys laevis* Say, 1 mm., to the largest forms including *Carabus gigas* Creutz 45–53 mm. long, of Europe; *Tefflus dispar* Sternberg, 50 mm. long, of West Africa; and the Australian species, *Catadromus elseyi* White and *Hyperion schroetteri* Schreibers, both attaining a length of 50 mm.

or more. One of the largest North American species is the beautiful green *Calosoma scrutator* LeConte which is only 35 mm. long.

The most important genera include the large cosmopolitan *Acupalpus* Latreille, *Calosoma* Weber, *Clivinia* Latr., *Dyschirius* Bonelli, *Lebia* Latr., *Tachys* Stephens, *Anisodactylus* Dejean, *Brachinus* Weber, and *Chlaenius* Bonelli are cosmopolitan with the exception of Australasia. The others are more limited as indicated: *Amara* Bonelli, *Bembidion* Latr., *Cymindis* Latr., *Harpalus* Latr., *Nebria* Latr., *Omophron* Latr., and *Trechus* Clairville all occur in Europe, Asia, Africa, and North America. *Calathus* Bonelli, *Carabus* Linn., and *Cychnus* Fab. inhabit Europe, Asia, and North America. *Platynus* Bonelli is indigenous to Europe, Asia, North America, and South America. *Scaphinotus* Latr. is North American, and *Zabrus* Clairville is European, African, and Asian. There are many remarkable forms that might be given special mention if space were available.

It is well to call attention to the habits of certain groups. Among the seed, plant, and berry destroyers are *Amara*, *Anisodactylus*, *Calathus*, *Clivinia*, *Harpalus*, *Omophron*, *Pterostichus*, and *Zabrus*. Arboreal forms include *Calosoma* and *Lebia*, which seek living prey. Although many forms are malodorous

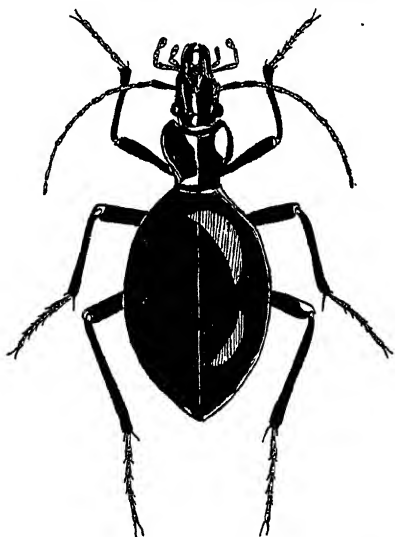


FIG. 179. The snail-eating carabid, *Brennus ventricosus* (Dejean). (Drawing by Carl Fuchs.)

there is probably none more offensive than *Nomius pygmaeus* Dejean, a small dark-brown or black species 7 mm. long, which occurs in southern Europe and across middle North America. One living specimen is sufficient to clear a room. The so-called bombardier beetles, which expel protective fluids and vapor-like, exploding bombs, include members of genus *Anthis* Weber, large African and Indian species whose discharge is irritating and painful to the skin, and particularly certain members of the genus *Brachinus* of which *B. tschernikhi* Mannerheim, of California and Arizona, an amber and blue species, 10 mm. long, is particularly famous. As these beetles flee from exposure when stones are

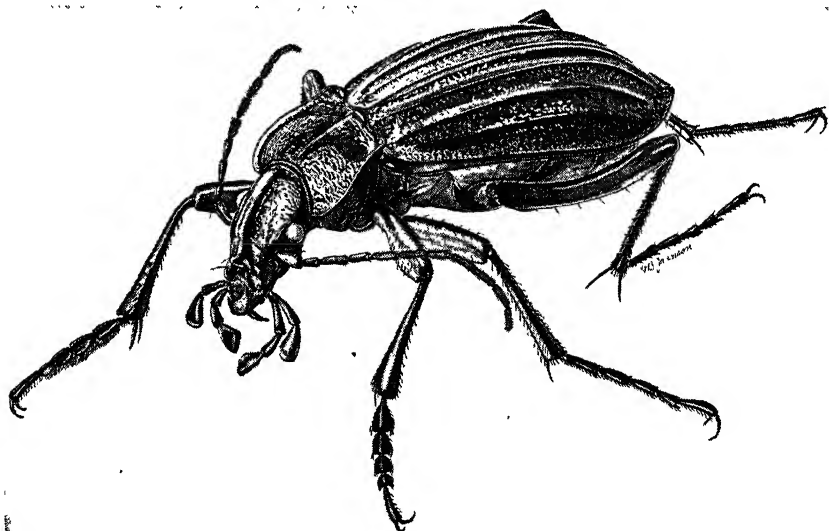


FIG. 180. *Carabus auronitens* Fab., a brilliant green and golden species common in the forests of central Europe.

turned, they make a most interesting display of miniature gas warfare, but are so active that the bombardment is often neither seen nor heard.

The unique *Promecognathous laevissimus* Dejean of California and Oregon is the only representative of an isolated genus.

Members of the genera *Cychrus*, *Carabus*, and *Scaphinotus*, and others with long slender heads, are destroyers of slugs and snails, the narrow head permitting the predator to reach into the shells of the hosts.

The large and elegant members of the genus *Calosoma* are among the most beneficial predatory insects since they are master hunters living on the ground and climbing trees in search of caterpillars, grubs, and other immature forms of destructive insects. They are smooth or beautifully sculptured, punctured and striated, and vary in color from the dusky and shining black, brown, and other somber colors to brilliant and iridescent green, blue, copper, and gold in various brightly marked temperate and tropical species. Probably the most

famous species is the large metallic-green European *C. sycophanta* (Linn.) which was introduced into the New England States by the U. S. Bureau of Entomology in 1905-1910 to prey upon the immature stages of the gypsy moth and brown-tailed moth in that region.

Family AMPHIZOIDÆ LeConte 1862.

A monogeneric family consisting of the genus *Amphizoa* Lec. and three species of small aquatic beetles which inhabit rocks and logs in fresh-water streams along the Pacific coast of North America and one species in Tibet.

Family HALIPLIDÆ Kirby 1837.

A group of small convex oval aquatic beetles, usually shining, spotted brownish-yellow, deeply punctured, free-swimming beetles, some species of which leave the water and roam along the sandy margins of streams at night. In the light of a lantern they resemble bright jewels. They comprise about 100 widely distributed species.

Family DYTISCIDÆ Leach 1815, 1817 (Dy-tis'ci-dæ, from the Greek *δυτικός*, able to dive; referring to the aquatic habits of the adults). German, Schwimmkäfer. Predacious Diving Beetles, Water Beetles, Dytiscids.

Small to large, oval, and flattened water beetles; hard, shining, smooth, punctured, or striated; somber-colored, black, dull green, brown, bronze, gray, and frequently bordered with dull yellow. Some few specimens are fairly brightly colored but there is little difference between tropical and temperate species in this regard. Head broad, fitting into the prothorax. Eyes well developed, mostly circular. Antennæ short, bare, filiform, 11-segmented. Mouth parts typically carnivorous. Mandibles crescent-shaped, sharp, hollow, permitting the sucking of body fluids. Galea two-segmented. Prothorax usually narrower than mesothorax. Wings well developed for flight. Elytra covering the abdomen. Legs adapted for aquatic life; fore and middle coxæ small, hind coxæ greatly enlarged, contiguous, fixed; femora short; tibiae short, flat, with long swimming hairs, and prominent apical spurs; tarsi five-segmented, with long swimming hairs, first three segments in male dilated and with cup-like suckers for clasping female. Abdomen with eight visible sternites, the apical segment tubular; two posterior pairs of spiracles are enlarged for air capacity. Larvæ caraboid, active; two pairs of ocelli may be present; long sickle-shaped mandibles; long hairy legs; eight-segmented abdomen, the last two segments furnished with long hairs which support the body head downwards on the surface film.

The adults and larvæ are wholly predacious and are voracious foes of many kinds of water insects and other aquatic animals such as mollusks, worms, tadpoles, salamanders, and fish. The adults are very active and may be observed hanging at an angle head downwards with the tip of the abdomen breaking the surface film and the hind legs raised and extended forward in

readiness for a quick getaway. They also hide in the mud or under debris on the bottom and cling to water plants. At night they may swarm over the land in quest of new water and often gather about strong lights. They are also attracted to bright tin roofs and automobiles. Adults are able to live on land for long periods, and innumerable specimens have been observed under stones in the bottom of dried pools and stream beds. Running and standing fresh water and rarely brackish water are inhabited, including thermal and rarely subterranean springs.¹ The eggs are laid in masses or separately on objects in the water or they may be inserted in the tissues of aquatic plants. The larvæ live a free and hunting life and because of their ferociousness are called water tigers.

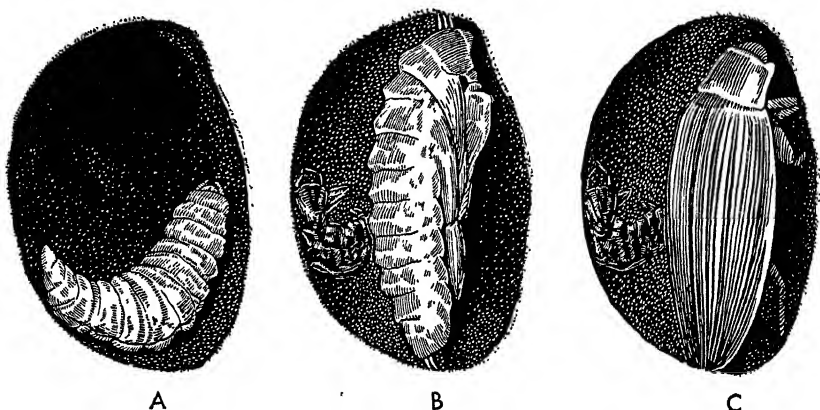


FIG. 181. The European predacious diving beetle, *Dytiscus marginalis* Linn., in cells in the ground. A, larva; B, pupa and cast larval skin; C, adult and cast pupal skin. (Drawn from photos by Hugh Main, 1934.)

They leave the water when mature and excavate a cell in the earth above the water line in which to pupate, the pupæ being terrestrial. In size the adults vary from the small black and gold European *Cœlambus confluentis* (Fab.), 2.5–3.0 mm., to *Dytiscus latissimus* Linn., the largest European species which is 36–44 mm. long.

The family contains about 90 genera and 2,050 species which are chiefly Holarctic although representatives are to be found throughout the world. The members are closely related to the predacious ground beetles of the family CARABIDÆ.

The important genera are *Canthydrus* Sharp, 80 spp. (cosmopolitan excepting Australia); *Laccophilus* Leach, 167 spp. (cosmopolitan); *Hyphydrus* Illiger, 53 spp. (Palæarctic, Ethiopian, Indo-Malaysian, Australian); *Bidessus* Sharp, 200 spp. (cosmopolitan); *Hydroporus* Clairville, 181 spp. (Holarctic, Neotropical, Australian). *H. marginatus* Duft and *H. melanarius* Strum are European, and *H. melanocephalus* Marsham is Holarctic. *Deronectes* Sharp, 72 spp.

¹ Certain members of the Palæarctic genus *Graptodytes* Seidlitz are blind and inhabitants of subterranean springs.

(Holarctic and Ethiopian); *Copelatus* Erichson, 196 spp. (cosmopolitan excepting South America); *Agabus* Leach, 162 spp. (Holarctic); *Hydraticus* Leach, 104 spp. (cosmopolitan); *Dytiscus* Linn., 27 spp. (Holarctic). *D. circumflexus* Fab. (Palearctic) and *D. marginalis* Linn. (Holarctic) are two very common species. *Cybister* Curtis, 64 spp., is cosmopolitan except for South America. Several of the common species such as *C. sugillatus* Erichson and *C. tripunctatus* (Olivier) are used by the Chinese for food and medicinal purposes. Dried specimens can now be purchased in the Chinese stores in San Francisco.























Eretes stictus Linn., a small ochreous species with black spots and punctures on the dorsum, 10–14 mm. long, is gathered around the brackish ponds of India as the larvæ leave the water for pupation in the soil and as the newly emerged adults seek the water. Both stages are used for food.

II. Superfamily GYRINOIDEA Leng 1920

Family GYRINIDÆ Leach 1815, 1817 (Gy-rin'i-dæ, from the Greek *γυρός*, round, circular movement; because of the gyrations of the adults on the surface of the water). German, Kreiselkäfer. French, Tourniquets. Whirligig Beetles, Surface Swimmers.

Small to medium-sized, elongate-oval, convex, smooth, shiny, active, aquatic beetles which are usually black in color and gyrate with great speed upon the surface of fresh water. The body is furnished with a lateral marginal keel which "rides" on the surface of the water. Head small and somewhat triangular. Antennæ short and thick; 11-segmented. Eyes large, divided so that upper parts are above and the lower portions below the surface of the water. Legs modified; the fore pair long, strong, and prehensile for grasping and holding prey; fore tarsi of males dilated and with suckers. Middle and hind legs short and paddle-like to propel the insects over the surface. Hind coxæ rigid. Wings developed in most forms. Abdomen with seven visible sternites. Larvæ aquatic, long, slender, flattened, with small head, well-developed legs, and a pair of lateral, plumose tracheal gills on each abdominal segment, and an extra apical pair on segment IX.

These beetles are familiar and interesting objects to all observers of nature and constitute a distinct and easily recognized group. They are predacious and air breathers but frequently dart to the bottom for rest and protection only soon to arise and glide like a figure skater on the surface. They usually occur in groups which may aggregate hundreds of individuals and prefer quiet, shallow water for their activities although many species definitely prefer streams and others ponds and lakes. The adults secrete an odor that is quite pronounced. They fly readily at night, and some are attracted to lights. The eggs are laid on objects in the water. The larvæ are predacious upon small aquatic animals and breathe by means of gills. They pupate in flimsy cocoons attached to rocks, sticks, water plants, and other objects in the water. In size they vary from the small European *Gyrinus minutus* Fab., 3.5–4.5 mm. long,

SUPERFAMILY	EXAMPLES	TARSAL FORMULA	ANTENNAE	ELYTRA	VISIBLE ABDOMINAL STERNITES
HYDROPHYLOIDEA		5-5-5	clavate, 6-9 segmented	covering most of abdomen	5 rarely 4 or 7
STAPHYLINOIDEA	 	3-3-3 to 5-5-5	simple or clavate	often abbreviated	5-8
CANTHAROIDEA	 	5-5-5 or apparently 4-4-4	filiform to clavate	rarely abbreviated	5-8
ELATEROIDEA	 	5-5-5	usually serrate or pectinate	usually covering most of abdomen	5
DRYOPOIDEA		5-5-5	variable, often serrate	usually covering most of abdomen	usually 5
DASCILLOIDEA	 	5-5-5	variable	rarely abbreviated	5
CUCUJOIDEA	 	3-3-3 to 5-5-4 or 5-5-5	variable but usually clavate	covering most of abdomen	5
MORDELLOIDEA	 	5-5-4	variable	covering most of abdomen	5-6
TENEBRIONOIDEA	 	5-5-4	variable but never pectinate	covering most of abdomen	5
PTINOIDEA	 	5-5-5	clavate usually	covering most of abdomen	5
SCARABAEOIDEA	 	5-5-5	lamellate	covering most of abdomen	6 rarely 5
CERAMBYCOIDEA	 	apparently 4-4-4	filiform rarely serrate	rarely abbreviated	5 rarely 6

Checkerboard Key

CORNEOUS ABDOMINAL TERGITES	LARVAL TYPE	HABITAT	FOOD HABITS	MISCELLANEOUS STRUCTURES
not more than 2	campodeiform	mostly aquatic	scavengers	maxillary palpi often longer than antennae
3 or more	campodeiform	terrestrial	scavengers and predators	wings without crossveins
not more than 2	campodeiform	terrestrial	mostly predators	integument soft
not more than 2	campodeiform	terrestrial	phytophagous, root-feeders wood-borers	prosternal process fitting into mesosternum
not more than 2	variable	aquatic	phytophagous	prosternal process, fitting into mesosternum
not more than 2	variable, campodeiform to eruciform	aquatic and terrestrial	phytophagous or scavengers	head not constricted posteriorly
not more than 2	variable, frequently campodeiform	terrestrial	phytophagous or predacious	head not constricted posteriorly
not more than 2	variable, hypermetamorphosis common	terrestrial	phytophagous or parasitic	head strongly constricted posteriorly
not more than 2	campodeiform, hard integument	terrestrial	mostly scavengers	head not constricted posteriorly
not more than 2	eruciform, legs short	terrestrial	phytophagous, mostly wood-borers	head often retractable
not more than 2	eruciform, legs long	terrestrial	phytophagous or scavengers	legs usually fossorial
not more than 2	eruciform, legs short or absent	terrestrial	phytophagous, leaf-feeders and wood-borers	third tarsal segmented usually bilobed

to the members of the remarkable tropical genera *Enhydrus* Castelnau of South America, *Macrogyrus* Regimbart of Australia and South America, and *Porrhorhynchus* Castl. of tropical Asia, all more or less brilliant metallic and measuring up to 12–15 mm. in length.

The most important genera are *Dineutes* MacLeay, cosmopolitan with 63 spp.; *Gyrinus* Geoffroy, nearly cosmopolitan with 80 spp. but absent in Australia; *Gyretes* Brullé of North and South America with 45 spp.; *Orectochilus* Lacordaire, in Asia, southern Europe, and northern Africa, the largest genus with 95 spp.; and *Orectogyrus* Regimbart in Africa and Madagascar with 70 spp. *Enhydrus* has four species, *Porrhorhynchus* five, and *Macrogyrus*, the most important genus in Australia, has 32. *Gyrinus huttoni* Pascoe, according to Tillyard, is the only representative reported in New Zealand.

B. Suborder POLYPHAGA Emery 1885

IV. Superfamily HYDROPHILOIDEA Leng 1920

Family HYDROPHILIDÆ (Leach 1815), Samouelle 1819 (Hy'dro-phil'i-dæ, from the Greek ὕδωρ, water, + φίλος, loving; water-loving beetles). German, Kolben, Wasserkäfer. Water Scavenger Beetles.

Minute to large, compact, oval, elongated, strongly convex, somewhat flattened, heavily chitinated, aquatic, subaquatic and land beetles which are

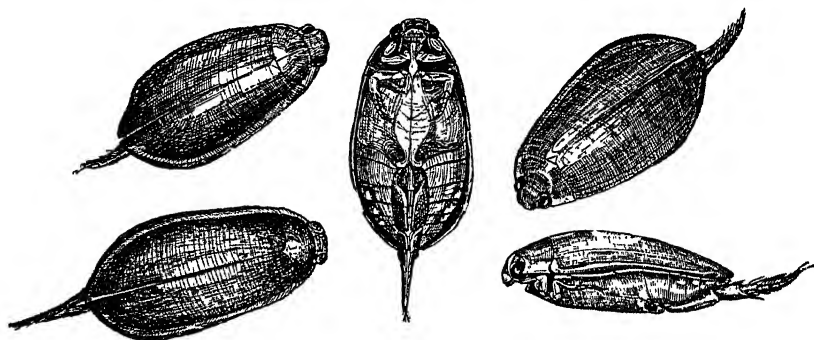


FIG. 182. Dried specimens of a Chinese predacious water beetle, *Dytiscus* sp., used for food by the orientals and purchased from Chinese merchants in San Francisco, California. This beetle occurs in immense numbers in the lower reaches of many of the great rivers in China.

smooth and highly polished or striated, punctured or dull. The colors are normally black, dull green, brownish, or yellowish, sometimes of soft or bright porcelain shades. Head short, usually wider than long and sunken into the prothorax. Eyes large. Antennæ very short; inserted in front of the eyes; often concealed beneath the head; six- to nine-segmented, the basal segment longest and sometimes curved; terminating in a large pubescent or hairy three- or four-segmented club in *Hydrous*. Mandibles strong and toothed. Maxillary

palpi often longer than the antennæ. Prothorax large and usually as wide as the rest of the body; the venter may have a strongly developed keel between the coxæ in certain aquatic genera. Legs long; the middle and hind pairs of the water forms furnished with long swimming hairs; tibiæ with long apical spurs. Tarsi five-segmented; the first may be minute, fore tarsi of males may be modified for clinging to the females. Elytra completely covering the abdomen, smooth, punctured, or striated. Wings well developed and enabling active flight. Air is carried in hairy air channels between the elytra and the abdomen although some authors state that air is also captured by the antennæ. Larvæ variable, long and slender, distinctly segmented; head small; legs large; lateral respiratory gill-like organs on abdominal segments I to VIII; and spiracles grouped on the last segment which may also support a pair of cerci.

The adults and larvæ are largely vegetable scavengers, but a few species are known to be predacious on water snails and probably on other aquatic animals. The land forms are mostly small and live along waterways, in damp marshy places, under wet bark of trees, in and under plant debris, many littoral under kelp, others in rotting cacti, dung, and among fungi. Some of these, at least, are thought to be predacious on other insects. The adults are active in all types of fresh water. They are frequently taken at lights at night and found stranded on the city streets in the early mornings. Many species æstivate and hibernate under stones and debris in the bottoms of ponds or streams that dry up during certain seasons. The range in size of the adults is considerable, varying from the minute black and brown European, *Cryptopleurum minutum* Fab., 1.6–2.0 mm. in length, to the largest European species, the great black water beetle, *Hydrous piceus* (Linn.), which attains a length of 35–50 mm. The eggs of these beetles may be carried beneath the bodies of the females until hatched, laid in cocoon-like masses or nidi which float, or attached to floating objects or to water plants. The larvæ are able to secure air from the water and do not come to the surface.

This large family, consisting of some 1,700 species is mostly tropical but is also very well represented in the temperate regions. The most interesting genus is *Hydrous* Dahl which is composed of a comparatively few large species occurring in Europe, Asia, and North America. The common European species are *H. piceus* Linn., already mentioned, and *H. aterrimus* Eschscholtz, which is 30–40 mm. long, while the common North American species is *H. triangularis* (Say), 23–37 mm. long.

Other aquatic genera common to Europe and North America are *Berosus* Leach, *Enochrus* Thomson, *Helochares* Mulsant, *Hydræna* Kugelann, *Hydrobius* Linn., *Hydrochus* Leach, *Hydrophilus* De Geer, and *Paracymus* Thomson. *Berosus* and *Hydrophilus* also occur in Asia and Australia, while *Helochares* occurs also in Asia and *Hydrobius* in New Zealand. A remarkable economic species, the turnip mud beetle, *Helophorus rufipes* Bosc, feeds on the roots and leaves of young turnip plants in England.

Genera that are subaquatic or littoral are *Cælostoma* Brullé of Europe and *Phænotum* Sharp of North America. Those that occur in wet vegetable debris,

dung, under bark, and in fungi include *Cyloma* Sharp of New Zealand, *Cercyon* Leach of Europe and North America, *Cryptopleurum* Mulsant of Europe, and *Megasternum* Mul. and *Sphæridium* Fab. of Europe and North America.

V. Superfamily STAPHYLINOIDEA Ganglbauer 1895

KEY TO IMPORTANT FAMILIES

1. Elytra short, leaving greater part of the dorsum of abdomen exposed; wings present, and when not in use folded beneath the short elytra; abdominal tergites entirely strongly chitinous or horny . . . 2
 Elytra usually long, covering the greater part of the abdomen, or if short, the wings are wanting or are not folded under elytra when not in use; abdominal tergites partly membranous . . . 3
2. Abdomen flexible, with seven or eight visible sternites; tarsi three- to five-segmented; body usually slender and often curved over the back. Small to large scavengers. (Rove Beetles.) . . . **STAPHYLINIDÆ** p. 546
 Abdomen rigid, with only five visible sternites; maxillary palpi large; tarsi three-segmented; body robust. Very small, usually brown beetles living in ants' nests. (Ant-loving Beetles.) . . . **PSELAPHIDÆ** p. 546
3. Posterior tarsi five-segmented . . . 4
 Posterior tarsi three- or four-segmented . . . 11
4. Antennæ elbowed and with a short compact club; elytra truncate behind, exposing last two abdominal segments; tibiae usually all dilated and front pair toothed; hind coxæ widely separated. Small robust, usually dull or shining black or red and black beetles living in carrion and dung. (Hister Beetles.) . . . **HISTERIDÆ** p. 548
 Antennæ rarely elbowed and not clavate . . . 5
5. Abdomen with five sternites, the fifth segment conically produced and as long as the three preceding ones; elytra not completely covering the abdomen; femur joined to side of trochanter; coxal cavities widely open behind; front coxæ large, conical, and contiguous; hind coxæ oval or transverse and widely separated. Very small oval shining species living in fungi, rotten wood, and other decaying vegetable matter. (Shining Fungus Beetles.) . . . **SCAPHIDIIDÆ** (Part)
 Abdomen with six or more sternites . . . 6
6. Front coxæ flat; elytra not longer than the prothorax and exposing five abdominal tergites; wingless; blind. Small beetles living on beavers. (Beaver Beetles.) . . . **PLATYPSYLLIDÆ** p. 546
 Front coxæ globular or conical . . . 7
7. Front coxæ globular; mentum large, the bases of the palpi distant; eyes rudimentary or wanting; antennæ long, 11-segmented. Minute beetles living in nests of rodents and on beavers, rare. (Rodent Beetles.) . . . **LEPTINIDÆ** p. 546
 Front coxæ conical . . . 8
8. Posterior coxæ widely separated . . . 9
 Posterior coxæ approximate; antennæ clavate; posterior tarsi slender . . . **SILPHIDÆ** (Part) p. 545
9. Eyes finely faceted or wanting; antennæ clavate or filiform; tibial

spurs large; apex of abdomen often exposed. Small to large flat or robust, somber or colored species feeding on carrion or decaying organic material. (Burying or Carrion Beetles.) . . . **SILPHIDÆ** (Part)

Eyes well developed and coarsely granulated 10

10. Elytra not entirely covering the abdomen; antennæ long, slender, sometimes filiform, 10- or 11-segmented; abdomen thick, conical, pointed, the last ventral segment elongate; tarsi long and slender

SCAPHIDIIDÆ (Part)

Elytra entirely covering the abdomen; antennæ expanding apically.

Minute shining or dull-brown or black somewhat hairy species occurring under bark, stones, and wet vegetable matter. (Ant-like Stone Beetles.) **SCYDMENIDÆ** p. 546

11. Tarsi three-segmented; abdomen with only three visible sternites; wings fringed with long hairs; head and eyes large; antennæ short, 11-segmented, clubbed. Rare, minute hemispherical shining species occurring under stones or in damp places. (Hemispherical Beetles.)

SPHERIIDÆ

Tarsi four-segmented; abdominal sternites distinct, not fused; wings not fringed with hairs; hind coxæ close together and with plates wholly or partially covering femora **SILPHIDÆ** (Part)

Family SILPHIDÆ Leach 1815 (Sil'phi-dæ, from the Greek *σῖλφῆ*, an insect, a beetle, a hookworm). German, Aaskäfer. French, Boucliers, silphides. Carrion Beetles, Burying Beetles, Sexton Beetles.

Minute to large (mostly medium-sized), broad or elongated and parallel-sided, soft or hard beetles which are somber-colored; black, brown, or gray with yellow, orange, or red markings; smooth, hairy, scaly, punctured, rugose, tuberculate, or rigid. Head usually prognathous, small or large, free and constricted basally or sunken into or covered by prothorax. Antennæ short; 11-segmented; variable in form but usually clavate or capitate with three or four enlarged terminal segments. Eyes large, or absent in cave-inhabiting forms. Ocelli, one pair present in the genus *Pteroloma* Gyllenhal. Mouth parts large: the mandibles especially well developed and the palpi prominent. Prothorax usually as wide as the mesothorax, about as long as wide, and variously shaped, frequently constricted basally. Wings well developed in most species. Elytra covering the body or even extended apically, or truncate and exposing the pygidium; often remarkably sculptured, and rarely tuberculate. Legs short and stout. Anterior coxæ conical and contiguous, posterior pair transverse and contiguous. Tibiæ fossorial and with spurs. Tarsi normally 5-5-5 but rarely 4-4-4 and heteramerous; fore and middle pairs dilated in the males. Abdomen with five or six visible sternites. Larvæ caraboid; broad, oval; armored or spined; plates overlapping dorsally; 10-segmented; six ocelli on each side of head; antennæ three-segmented; legs well developed; a pair of pseudocerci or urogomphi; and the terminal segment pseudopod-like.

These beetles comprise a small family of about 1,600 species which are largely saprophagous and many of which are attracted to dead animals. The burying or sexton beetles, particularly those belonging to the genus *Necroph-*

orus Fab., undermine and bury small animals and utilize the carcasses for their young. The European *N. humator* Fab., 18–25 mm. long, *N. germanicus* Linn., 20–30 mm. long, and the American *N. marginatus* Fab., 20–27 mm., and *N. pustulatus* Herschel are common species. Another well-known genus is *Silpha* Linn., species of which may be scavengers as well as plant feeders or even predacious on snails. *S. lapponica* Herbst, 12 mm., and *S. obscura* Linn., 13–17 mm., are carrion feeders common in Europe and North America. *S.*

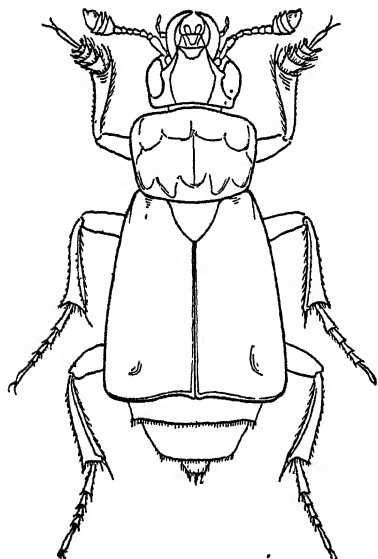


FIG. 183. The black carrion beetle, *Neocrophorus pustulatus nigratus* Mannerheim. (From *Insects of Western North America*.)

opaca Linn., 10–14 mm., *S. ramosa* Say, 12–18 mm., and *S. bituberosa* Lec., 12 mm., are all destructive to plants. They occur in North America and the first also in Europe.

Family SCYDMÆNIDÆ (Leach 1815).

Includes very small, smooth and hairy, somber-colored species living under mosses, bark, stones, and in ants' nests. Cosmopolitan, with 1,200 species.

Family PSELAPHIDÆ (Leach 1815).

Minute brachypterous, yellowish and reddish beetles having eyes with few large granular facets and with habits and distribution similar to those in the preceding family.

Family LEPTINIDÆ LeConte 1866.

Very small, blind or nearly blind species. Members of *Leptinus* Müller occur in the nests, and rarely on the bodies, of small rodents, in the nests of birds, wasps, and bumblebees, and in rotten wood. Widely distributed.

Family PLATYPSYLLIDÆ Ritsema 1869.

This family includes a single species, the beaver beetle, *Platypsyllus castoris* Rits., which is permanently ectoparasitic on the European and North American beavers.

Family STAPHYLINIDÆ (Leach 1815), 1817 (Staph'y-lin'i-dæ, from the Greek σταφυλῖνος, a kind of insect). German, Kurzflügler, Raubkäfer. Rove Beetles.

Minute to medium-sized, active, elongated, parallel-sided and usually somewhat flattened or nearly cylindrical beetles characterized chiefly by their very short and truncate elytra that expose much of the abdomen, which is flexible

and often curled up and forwards over the rest of the body; integument soft, leathery, or hard; smooth and shining or partly to wholly pilose or densely hairy. Head large, often as wide as the rest of the body, free, prognathous. Eyes small or large, rarely wanting. Ocelli, consisting of one or two, may also be present. Antennæ 10- or 11- (rarely nine-) segmented, variously placed on the margins of the head, filiform or clavate. Mouth parts conspicuous and with very large powerful mandibles which may overlap when closed. Legs short and strong and permitting rapid movements. Tarsi variable, usually 5-5-5, but may be either 4-5-5 or 3-5-5. Elytra short, never as long as the abdomen, usually less than half as long; absent in littoral and other forms. Wings absent, reduced, or developed for flight. Abdomen truncate or pointed, flexible, moved up and down over back, and aids in folding the wings and perhaps also for protection; six or seven visible sternites; spiracles visible or hidden; and with styliform appendages. The larvæ do not differ greatly in appearance from the adults except in the lack of elytra and wings. They are often similarly colored and move about like the mature forms.

These beetles form one of the largest groups of insects and include more than 20,000 species. They occur throughout the world and represent a wide variety of forms and habits. As a whole they are carnivorous and saprophagous and, like all predators and many phytophagous insects, they are also cannibalistic. The adults occur in and about carrion and decaying organic matter, dung, and debris wherever they are able to find food. They form the largest group of myrmecophilous insects with more than 300 species associated with ants.

A number of very small species like *Anthobium minutum* Fab. and *A. torquatum* Marsham of Europe, *Trogophlæus pusillus* (Gravenhorst) of Europe and North America, and *Apocellus sphaericollis* Say of North America feed on the foliage of succulent plants, on pollen, and on strawberries. Many species are odorous and eject volatile liquids as a means of protection. These fluids can actually be seen escaping from the tip of the abdomen as a very fine mist expelled with much force. Others exude drops which are smeared upon the adversary by means of the flexible abdomen. In size the members vary from the minute *Oligota pusillima* Grav., 0.7 mm. long, of Europe and North America to the largest European species, *Staphylinus tenebricosus* Grav., which measures 22-30 mm. in length, and *S. olens* Müller, which is 20-32 mm. long.

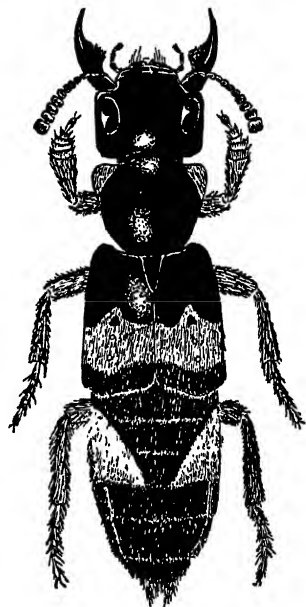


FIG. 184. The hairy rove beetle, *Creophilus maxillosus villosus* (Gravenhorst). (From *Insects of Western North America*.)

Species of *Oligota* Mann. and *Somatium* Wollaston are minute predators on plant-feeding mites. The small *Atheta* Thomson often swarms over the countryside in the fall of the year and not infrequently lands in the eyes, ears, noses, and mouths of people. According to Imms (1937) the first hatched larvæ of *Aleochara* Grav. are caraboid, but after they find and enter the puparia of the dipterous genus *Anthomyia* they transform to a scarabæoid second stage.

One of the commonest large species is the hairy rove beetle, *Creophilus maxillosus* (Linn.), a black-and-yellow-banded beetle 12–22 mm. long, which is almost always to be found in dead animals where it feeds upon carrion insects in Europe and North America. The Australian Devil's Coachhorse, *C. erythrocephalus* Fab., black with red head, is a conspicuous species in Australia while the Devil's Coachhorse of Great Britain and Europe is *Staphylinus olens* Müller which is a ferocious hunter.

The largest North American genera are: *Atheta* Thomson, *Bledius* Mann., *Oxyptoda* Mann., *Philonthus* Curtis, *Quedius* Stephens, *Stenus* Latr., and *Trogophloeus* Mann.

Family HISTERIDÆ (Leach 1815), Samouelle 1819 (His-ter'i-dæ, derivation not clear; thought to be derived from the Latin *hister*, the original Etruscan form of *histrio*, a comedian or player; from the peculiar form or harlequin colors¹). German, Stutzkäfer. Hister Beetles, Steel Beetles.

Minute to medium-sized, hard, compact, oval or rectangular, flat or somewhat cylindrical beetles which are smooth and polished, punctured, or striated; mostly black, some with yellow, orange, or red markings, others brown, reddish, or metallic, with rainbow reflections. Many members are among the most bizarre of all insects. Head small and retractile, sunken into prothorax and sometimes partly surrounded by the anterior angles of the latter. Eyes prominent, mandibles often large and extending forward. Antennæ geniculate; scape long, curved, sometimes leaf-like, followed by seven small segments and a three-segmented club or knob. Prothorax large, almost as long as the rest of the body; rigid. Legs short, stout, retractile; tibiæ fossorial; tarsi five-segmented, 5–5–4 in some ABRÆINÆ which also have the first and second hind tarsal segments fused instead of the fourth and fifth as is usually the case; hind coxæ widely separated. Elytra truncate and exposing the two posterior abdominal segments, giving the body a rectangular appearance. Wings well developed in most species and permitting rapid flight. Larvæ cylindrical, soft, wrinkled, and without labrum or ocelli; mandibles large; legs short, often with foliate tibiæ; body segmented and tuberculate or with short spines and a pair of two-segmented cerci, at least in some genera.

These beetles are frequently associated with dung and carrion and were until within comparatively recent years, supposed to be saprophagous. They are now known to be generally predacious on the saprophagous insects which, though buried in the soil, they can reach by the aid of their strong fossorial tibiæ.

¹ See John E. LeConte, *Proc. Acad. Nat. Sci. Philadelphia*, p. 310, 1859. Possibly also from the Greek *ὑστρεος*, rudimentary, elementary. Etruscan *histrio*, one who makes others laugh.

Many forms occur in sandy places and may be taken on the ocean beaches, along water courses, and in semiarid and arid desert wastes. Some species live under the bark of dead trees and in the burrows of other wood-infesting insects, preying upon these and other animals which occur there. Others are myrmecophilous or termitophilous. Still others occur only in the burrows of certain rodents and land tortoises. When disturbed the adults retract the head and legs and feign death. In this condition I have seen the wind roll them along over sandy stretches with considerable violence.

The family is one of the most interesting among beetles and yet one that has received very little careful attention, so little, in fact, that in a great many species the sexes have not been separated. Careful work with the genitalia will soon clear up many problems connected with their classification. The members are widely distributed over the world and number no less than 3,000 species. In size they vary from the small black European *Acrilus nigricornis* Hoffman, 0.6–1.0 mm. in length, to the large flat primitive (cosmopolitan) species of *Hololepta* Paykull, some of which are as thin as paper and measure from 10–15 mm. in length. *Hister major* Linn., a brilliant black European species, attains a length of 14 mm.

The genus *Saprinus* Erickson is the largest and most widely distributed, being practically cosmopolitan. It has over 100 North American species. *Hister* Linn., a close second, is widely dispersed and has between 90 and 100 species in North America. The primitive genus *Hololepta* is known to occur in Europe, Asia, and North America. *Onthophilus* Leach, a form with deeply striated or ridged pronotum and elytra, is Holarctic. Genera common to North America and Europe are *Acrilus* Lec. (tarsi 5–5–4), *Dendrophilus* Leach, *Paromalus* Erickson, *Plegaderus* Er., and *Heterius* Er. Some of the important myrmecophilous genera are *Dendrophilus* Leach (in part). *Heterius* Er. listed above are generally with *Formica* spp. while the Australian *Chlamydopsis* Westwood and *Pheidolephila* Lea, and *Terapus* Marseul, of North and South America, are usually associated with *Pheidole* spp.

Two interesting species are the minute tick-like *Sternocelis arachnoides* Fairmaire, brown and but 1 mm. long, of the Mediterranean region, and the brown long-legged *Teratosoma longipes* Lewis, 1.5–2.0 mm. long, of Brazil. The cylindrical African *Dolicholister filiformis* Bickhardt, 2 mm. long, is a brown punctate species in which the head and prothorax equal the rest of the body. Other genera having cylindrical species are *Pygocelis* Lewis, *Trypanæus* Eschscholtz, *Trypeticus* Marseul, and *Trypobius* Schaum.

VI. Superfamily CANTHAROIDEA Reitter 1906

KEY TO IMPORTANT FAMILIES

1. Abdomen with seven or eight visible sternites 2
 Abdomen with six visible sternites 4
2. Middle coxæ distinct; epipleura wanting; elytra usually with reticulated surface; no phosphorescent organs. Largely tropical beetles.

- (Net-winged Beetles.) **LYCIDÆ** p. 551
 Middle coxæ in contact; epipleura distinct; elytra not reticulate . . . 3
 3. Episterna of metathorax sinuate on inner side; head nearly or quite covered by thorax; epipleura usually wide at base of elytra; phosphorescent organs usually present. (Fireflies.) . . . **LAMPYRIDÆ**
 Episterna of metathorax not sinuate on inner side; head fully exposed; epipleura narrow at base; anterior coxæ with distinct trochantins; elytra soft; no phosphorescent organs. Medium-sized predacious beetles. (Leather-winged Beetles.) **CANTHARIDÆ** p. 552
 4. Hind coxæ prominent, at least internally 5
 Hind coxæ flat, not prominent 6
 5. Body with extensible vesicles **MALACHIIDÆ** p. 552
 Body without extensible vesicles **MELYRIDÆ** p. 552
 6. Fourth segment of tarsus small; pronotum separated from propleura **CORYNETIDÆ** p. 553
 Fourth segment of tarsus normal; pronotum not separated from propleura **CLERIDÆ** p. 552

Family LAMPYRIDÆ Leach 1817 (Lam-pyr'i-dæ, from the Greek *λαμπυρίς*, a glowworm; referring to the luminous larviform females). German, Leuchtkäfer. Fireflies, Glowworms.

Small to medium-sized, flat soft-bodied elongated nocturnal beetles, which are usually smooth or slightly pubescent; black, brown, yellow, or red in color and luminous¹ in many species. The adults are either beetle-like in form or the females of a number of genera are larviform and totally different from the males. Head small, free or wholly or partly covered beneath the pronotum; rarely somewhat prolonged into a snout. Antennæ inserted on the frons, 11-segmented, pectinate or flabellate in the males. Eyes may be very large in the males. Thorax large, pronotum covering head in some forms. Legs normal. Fore coxæ subconical, middle contiguous, hind transverse. Tarsal formula 5-5-5 or rarely 4-5-5 in males. Elytra leathery, long or reduced, and not always meeting in a straight line at the apices. Wings well developed except in the larviform females. Abdomen with six to seven visible sternites, the first immovable. Luminous organs on segments VI and VII and also on others. The light is variable and may be present only in the female glowworms; in other species it may be stronger in either sex; in color the light varies from yellowish-green to green, orange, or red. The eggs,² larvæ, and pupæ of certain forms may also be luminous. The larvæ are flat, elongated, distinctly segmented; head small with sickle-shaped mandibles; legs well developed; thoracic and abdominal tergites sclerotized; photogenic organs may be present on a pair of round patches on abdominal segment VIII.

¹ Luminosity occurs in a number of widely separated groups of insects in the families ELATERIDÆ, LAMPYRIDÆ, and PHENGODIDÆ in the order COLEOPTERA and in the family MYCETOPHILIDÆ of the order DIPTERA. The luminous organs are composed of cells which are developed from the fat body but have many more nerves and tracheal capillaries which are thought to aid in oxidation and combustion which produce the light. (See Balduf, *Bionomics of Entomophagus Coleoptera*, pp. 87-94, 1935.)

² In reality the embryonic larvæ become luminous before hatching from the eggs.

The members of this family are among the most interesting and remarkable of all living creatures. A display of fireflies on a warm summer night is beyond description and rivals any other natural phenomenon. The larvæ and adults are predacious upon small animals including earthworms, snails, crustaceans, and insects. They frequent moist and damp locations or warm regions where summer rains are abundant, but glowworms may occur in regions where little or no summer precipitation occurs. In temperate and subtropical regions these insects frequent marshes, swamps, woods, and areas along streams. A few species live on exposed grassy hillsides. The remarkable luminous displays, which are frequently synchronized, have fascinated travelers and naturalists throughout the ages. In early days glowworms and beetles were held captive in glass containers for the light which they might produce, and varied and fabulous are the tales related about these beetles.

The family is primarily tropical and subtropical with a large number of representatives in the temperate regions. There are about 2,000 described species. The common European glowworm, *Lampyrus noctiluca* (Linn.), is one of the best known members of the order. The males are normal, blackish brown, and 11–12 mm. long, whereas the females are larviform, light brown, and 16–18 mm. long. The females are luminous on warm July nights. *Phosphæus hemipterus* Goeze is another interesting European species in which both sexes are beetle-like, but the elytra and wings are abbreviated, or absent in the females, so neither can fly. They are 5.5–10.0 mm. long, and emit but a feeble light, perhaps because they are, as some believe, largely diurnal.

The two most important luminous genera in North America are *Photinus* Lacordaire and *Photuris* LeConte. The members occur east of the Rocky Mountains and north to the Great Lakes. They are the beautiful fireflies that flash their tiny lights beside the streams, ponds, and lakes and over the marshes, meadows, and lawns on warm summer evenings. Both sexes are luminescent and winged. The genus *Microphotus* Lec. is also American and is best represented in the more arid southwestern areas. The males are winged whereas the females are larviform and luminous. *M. angustus* Lec. ranges from Florida to California.

Phausis Lec. is both European and North American and has one species, *P. splendidula* (Linn.). The males are winged and the females larviform. *Lucidota* Laporte is the largest genus in North America, being represented by 13 species. Both sexes are normally winged, diurnal, and either lack, or have but slightly developed, light organs. Luminescent organs appear in the larvæ of *L. fenestralis* (Melsheimer) and other species but are lacking in the adults. The pupæ of *Luciola cruciata* Motschulsky and *L. lateralis* Mats. of Japan and of *Lamprophorus tenebrosus* Walker of Ceylon are luminous (Baldus, 1935).

Family LYCIDÆ Lacordaire 1857.

The net-winged beetles are closely related to the LAMPYRIDÆ. They are beautifully colored and soft-textured rather small tropical and subtropical predacious species which are not luminous.

Members of family MALACHIIDÆ Leach 1815 and family MELYRIDÆ Schaum 1859 are closely related small and metallic leaf- and flower-visiting beetles which are chiefly Holarctic and include about 1,500 species. Many known species of *Collops* Erichson and *Malachius* Fab., especially of the former, are predacious on other insects while others are scavengers.

Family CANTHARIDÆ¹ Heyden, Reitter, and Weise, 1883 (Can-thar'i-dæ, from the Greek *καθαρῖς*, a blistering fly or a kind of beetle). German, Weichkäfer, Schusterkäfer. Leather-winged Beetles, Soldier Beetles.

Medium-sized, narrow, elongated, somewhat cylindrical beetles with soft integument and leather-like elytra; smooth, velvety, punctured, or sculptured. Head prognathous, free, and with narrow neck. Antennæ long, filiform or serrate, widely separated, 11-segmented. Mandibles simple or toothed. Prothorax free and usually narrower than mesothorax. Legs long and slender; trochantins of fore pair well developed; tarsi five-segmented. Elytra covering the abdomen or short. Abdomen with seven or eight visible sternites. Larvæ elongated, distinctly segmented, velvety, with flat chitinated head, short antennæ, a single ocellus on each side, and vestigial anal pseudopod. The members of this family appear to be predacious in both the larval and adult stages, but the adults of certain species also feed on pollen and nectar. The larvæ are found on the ground and under bark where they feed upon such living insects as may be captured whereas the adults are mostly active fliers that feed upon aphids, mealybugs, and other small plant-infesting insects. Some of the adults which occur in damp places are very sluggish.

The family is composed of 1,300 species, quite widely distributed. The important temperate genera are *Cantharis* Linn., *Chauliognathus* Hentz, *Dasytes* Paykull, *Malthinus* Latr., *Malthodes* Kiesenwetter, *Podabrus* Westwood, *Polemium* Lec., *Rhagonycha* Esch., *Silis* Latr.

The commonest forms are the dusky or tan-colored leather-winged beetles belonging to the genus *Podabrus* which commonly feed upon members of the APHIDOIDEA and COCCOIDEA.

Family CLERIDÆ (Billberg 1820), Kirby 1837 (Cler'i-dæ, from the Greek *κλήρος*, a destructive insect in beehives; referring to a species in this family). German, Buntkäfer. Checkered Beetles, Clerid Beetles.

Small to medium-sized, usually elongate, slender or cylindrical, rather soft-bodied beetles which are smooth or hairy and scaly; dull or brightly colored and spotted red, yellow, and other shades, often metallic blue. Head at least subhypognathous, partly sunken into prothorax, often as wide as the prothorax. Eyes conspicuous. Antennæ simple, dentate, serrate, flabellate, clavate; 11-segmented, with three terminal segments greatly enlarged to form a loose club. Palpi enlarged, last segment dilated; labial palpi often largest. Prothorax normally narrower than meso- and metathorax, frequently widest anteriorly.

¹ Also known as TELEPHORIDÆ Leach 1815. The medicinal cantharides is obtained from *Lytta vesicatoria* (Linn.) and other species of beetles belonging to the family MELOIDÆ.

Elytra leathery, usually covering body but sometimes exposing tip of abdomen. Wings well developed or absent. Legs typical; anterior coxæ large, conical, contiguous; hind coxæ small, sunken, transverse. Tarsi usually 5-5-5, rarely 4-4-4. Abdomen with five or six visible sternites. Larvæ caraboid, cylindrical or normally somewhat flattened, distinctly segmented; hairy; frequently yellow, brown, pink, or red; with corneous plates on the pronotum and apical abdominal segment — the latter may have two horn-like urogomphi. They are usually to be found in the soil frequenting the nests of bees and wasps, the egg capsules of locusts and grasshoppers, cells of bees and wasps above ground, beehives, and the burrows of wood-boring and barkbeetles, where they feed upon the eggs and larvæ of these hosts. The adults are also predacious and are particularly beneficial in destroying certain destructive barkbeetles; certain few genera such as *Trichodes* visit flowers.

The family is a relatively small one, consisting of some 2,500 species, and is particularly well developed in the tropics. The important genera are: *Cymatodera* Gray, 87 spp. (Holarctic). *C. ovipennis* Lec. 8-11 mm., pale brown, wingless, feeds on barkbeetles, wood borers, and larvæ of the codling moth. *C. æthiops* Wolcott has similar habits. Both are North American. *Thanasimus* Latr., 39 spp. (Holarctic, Indo-Australian). *T. formicarius* (Linn.), 11-15 mm., black and green, is a common European species. *Enoclerus* Gahan, 158 spp. (North and South American). *E. sphegeus* (Fab.) is an important predator on barkbeetles. *Ommadius* Castelnau, 114 spp. (Indo-Malaysian, Australian). *Trichodes* Herbst, 78 spp. (Holarctic). *T. alvearius* (Fab.) and *T. apiarius* (Linn.) of Europe both invade beehives and attack the bee larvæ. *T. apivorus* Germar, of North America, feeds on the larvæ of wild bees and wasps. *Aulicus* Spinola, 8 spp. (North American) has one species, *A. terrestris* Linsley of California, the larvæ of which are known to eat grasshopper eggs. *Hydnocera* Newman, 103 spp. (North and South American). *Lemidia* Spinola, 75 spp. (Australia and New Zealand).

In the closely related family CORYNETIDÆ are placed the three cosmopolitan species of *Necrobia* Olivier. The red-legged ham beetle, *N. rufipes* (De Geer), is iridescent greenish-blue with bases of the antennæ and the legs reddish, 3-5 mm. long. This beetle is famous for being said to be instrumental in saving the life of the greatest French entomologist, P. A. Latreille, in 1793. It is also known as the copra beetle because it swarms over the ships carrying this dried product. The other two species are *N. ruficollis* Fab., greenish-blue with bases of the elytra and the legs red, 4-6 mm., and *N. violacea* (Linn.), greenish-blue with the antennæ and legs wholly black; 3-5 mm. long. These beetles feed upon animal and cereal products.

IX. Superfamily ELATEROIDEA Leng 1920

KEY TO IMPORTANT FAMILIES

1. First two abdominal sternites fused or immovable; tarsi with membranous lobes beneath; thorax and abdomen firmly united; antennæ

- serrate, 11-segmented. Small to large, often beautiful metallic and iridescent beetles. (Metallic Wood-Boring Beetles.) . . . **BUPRESTIDÆ** p. 556
- All the abdominal segments free and movable 2
2. Prothorax firmly attached to the mesothorax, not movable; front coxal cavities closed behind by mesosternum; prosternal process prolonged but not movable. Minute black or brown beetles. (Pseudo Click Beetles.) **THROSCIDÆ**
- Prothorax loosely joined to the mesothorax and freely movable, the hind angles each prolonged into a tooth; prosternal process loosely received in a socket in the mesosternum; front coxal cavities entirely within the prosternum 3
3. Prosternum lobed in front; labium visible; prothoracic process movable and when thrust into the socket on the mesosternum and forcibly snapped out causes the beetle to jump and click. Small to large, mostly brown and black beetles. (Click Beetles.) . . . **ELATERIDÆ**
- Prosternum not lobed; labium concealed; antennæ inserted on front, somewhat distant from eyes; not able to jump and click. Small and rare beetles, **EUCNEMIDÆ**

Family ELATERIDÆ Leach 1815, 1817 (El'a-ter'i-dæ, from the Greek *ελατήρ*, a driver, a charioteer). German, Schnellkäfer. French, Taupins. Click Beetles, Skipjacks, Snapping Beetles.

Minute to medium-sized, hard, elongated and somewhat flattened beetles which are somber-colored — black, gray, and brown — in the temperate regions and brilliant metallic in the tropics; smooth, punctate, striated, rugose, hairy, or scaled. Head small and partly sunken into prothorax. Antennæ simple, serrate, pectinate; inserted near the eyes; 11-segmented. Eyes prominent and rounded. Mandibles bifid. Prothorax large, free, and with the posterior angles usually produced and pointed and with a prosternal process which engages a mesosternal socket. Drawing the process almost out of the socket and then forcibly slipping it back again causes the clicking or snapping noise and the hurtling of the insect's body into the air, a most startling experience for those unfamiliar with these beetles. Legs short, often somewhat retractile; anterior coxal cavities formed by the prosternum; hind coxæ with a plate extending below the femur; tarsi five-segmented; claws simple, toothed, or pectinate. Elytra covering the body in most species. Wings normally well developed enabling the insects to fly rapidly. Abdomen with five visible sterna; the apical one movable. Larvæ, frequently called *wireworms*, are usually long and cylindrical but some are somewhat flattened. Body tough and elastic, smooth, and shining, yellow or reddish-brown in color. Segment IX with a chitinated dorsal plate margined with teeth and furnished with chitinated simple, paired, or compound processes or hooks and also with an anal pseudopod. Head chitinated. Simple eyes present. Antennæ three-segmented.

In size the adults vary from the minute *Quasimus minutissimus* Germar, of Europe, which is only 2 mm. long, to the large *Alaus gibboni* Newman, of Aus-

tralia, which is 50 mm. in length, and the African *Tetralobus flabellicornis* (Linn.), up to 65 mm. in length. The adults are to be found on the ground, in decayed wood, and resting on plants of all kinds. Certain species visit flowers and a number do considerable damage by eating the buds of deciduous fruit trees and shrubs in the early spring.

The larvæ of many species live in dead wood and under debris but by far the greater number are subterranean and feed upon seeds and plants in and on the surface of the soil. The hairy larvæ of the giant African skipjack, *Tetralobus flabellicornis* (Linn.), live in the nests of termites. The larvæ are often present in great numbers and are among the most injurious pests to truck,

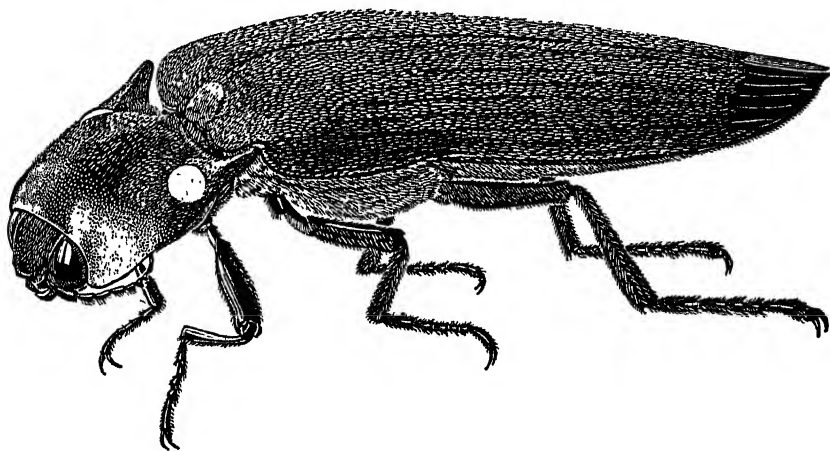


FIG. 185. A fire beetle, *Pyrophorus peltatus* Eschscholtz, one of the remarkable luminous elaterids of tropical North and South America. It is a beautiful metallic green with yellow prothoracic luminous spots.

cereal, and forage crops throughout the world. Those of some members are carnivorous. The eggs are laid on rotten wood, in debris, and on or in the soil. The larvæ reach full development in from 2 to 5 years.

The family is a large and varied one, consisting of upwards of 8,000 species, and is well represented in all parts of the world.

The most remarkable members are the fire beetles belonging to the genus *Pyrophorus* Illiger of tropical North and South America which contains 112 species. The best known species, the cucubano, *P. luminosa* Illiger, of the West Indies, is 25 or more mm. long and emits a brilliant greenish light from a pale spot on either side of the base of the pronotum and a reddish light from the venter of the abdomen. Other species, particularly the cucujo, *P. noctilucus* (Linn.) and *P. phosphorescens* Castlenau, are similarly luminous. So remarkable is the appearance of the swarms of these beetles that they have been discussed at great length by nearly all early travelers and conquerors in these regions. Wolcott (1933) states that the larvæ of the former are also luminous

and are beneficial because they feed upon such agricultural pests as white grubs and other insect larvæ in the soil.

The important genera are: *Agriotes* Eschscholtz, 230 spp. (cosmopolitan). It contains two cosmopolitan species: *A. lineatus* (Linn.), destructive to truck and field crops, and the wheat wireworm, *A. mancus* Say, of North America. *Alaus* Eschscholtz, 178 spp. (cosmopolitan). Large beetles from 25–50 mm. long with the larvæ somewhat longer, which breed in dead wood. The larvæ of some species are said to be predacious. *Athous* Eschscholtz, 230 spp. (Holarctic, Neotropical, Oriental). *Cardiophorus* Esch. 472 spp. (cosmopolitan). The adults feed on the buds and foliage of deciduous trees in temperate regions. *Conoderus* Esch. (*Monocrepidius* Esch.) 337 spp. (cosmopolitan). A number of species are serious pests of cereal and field crops in North and South America. *Corymbites* Latr., 171 spp. (cosmopolitan), contains many species injurious to agricultural crops. *Elater* Linn., 181 spp. (cosmopolitan, excepting South America), inhabits forested areas. *Hemicrepidius* Germar, 36 spp. (Nearctic, Neotropical, Indo-Malaysian). In it are many economic species. *Horistonotus* Candeze, 101 spp. (Nearctic, Neotropical, Oceanian). *H. uhleri* Horn is the corn and cotton wireworm of the southern states. *Ludius* Berthold, 62 spp. (cosmopolitan). *Melanotus* Esch., 196 (cosmopolitan). Adults visit flowers, and those of *M. rufipes* Herbst injure buds of fruit trees in the Holarctic region. *Pheletes* Kiesenwetter, 22 spp. (Holarctic). Pests of cereal and forage crops.

Family BUPRESTIDÆ Leach 1815, 1819 (Bu-pres'ti-dæ, from the Greek *βούπρηστος*, a mythical poisonous beetle which if eaten by cattle caused bloating and death; derived from *βόψ*, bull, ox, cow, + *πρήθειν*, to blow up). German, Rachtkäfer. Buprestid Beetles, Metallic Wood Borers, Flat-headed Borers.

Medium to large, hard, flat and short or elongate and cylindrical, metallic beetles which are particularly characterized by their copper, bronze, gold, green, and other brilliant metallic colors with green, red, and purple iridescences which make them among the most prized of all insects. The tropical forms are especially beautiful and often bizarre. Some species have exquisite procelain colors. The surface is smooth and polished, punctate, rugose, striate, pollinose, and even hairy or scaly in some few forms. Body compact, with head sunk into the prothorax to the eyes. Antennæ inserted on the front, short, serrate, 11-segmented. Eyes large. Prothorax large and immobile; pronotum flattened; prosternum extending into mesosternum and in some even into the metasternum. Elytra usually covering abdomen. Wings normally well developed, large, and permitting rapid flight. Legs: anterior coxæ globular, hind coxæ dilated and partly covering bases of femora; tarsi five-segmented, the first four pad-like. Abdomen with five visible sternites, the first two fused, and the pygidium covered or exposed.

These beautiful beetles are largely restricted to forested areas and require woody plants and trees for breeding purposes. The adults are primarily sun-lovers and are most active during the brightest and hottest hours of the day.

While some of them bask on the exposed limbs and trunks of trees, others visit foliage and a considerable number are to be seen on flowers. The females oviposit on or in the cracks of the bark, and, while injured, dying, and recently killed plants are preferred, certain species attack perfectly healthy trees as well as the cones of coniferous trees. A number of species are either attracted by or become unusually activated by forest fires and smoke and are quite annoying to woodsmen by biting their necks, hands, and other exposed parts of the body.

The brilliant and fast colors have long attracted attention. The elytra and other parts of the bodies have been used in embroidery and the arts, and the smaller beetles have been treated as gems by jewelers. Among the most attractive and brilliant species so used are: *Sternocera chrysioides* Castelnau and Gory, a brilliant green species of India, China, and Japan; *Calodema regalis* Laporte and Gory, brilliant green and orange, and *C. plebeja* Jordan and Gory, brilliant green and black, very beautiful Australian species; the Japanese *Chrysochroa fulgidissima* Schönherr, brilliant green with two reddish longitudinal stripes, and *C. holsti* Waterhouse, brilliant green with the tips of the elytra red; and the Chinese and Indian *C. chinensis* C. and G., green and red, and *C. edwardsii* Hope, yellow-spotted. They are also sources of considerable income to collectors.

One of the smallest species is *Trachys minuta* (Linn.), violet and bronzy-black and only 3.0–3.5 mm. long, while one of the largest is the fine Brazilian *Euchroma gigantea* (Linn.), a dark metallic species with striated and sculptured elytra with green, red, and purple iridescence, which attains a length of 60 mm. and a width of 25 mm.

The larvæ are blind, legless, distinctly segmented, elongated and often slender with very small head and a greatly enlarged and usually flattened thorax which has given rise to the common name "flat-headed borers." They taper posteriorly and are more flattened than cylindrical; nine-segmented; soft and smooth; and usually white or yellowish in color. They have powerful mouth parts and are capable of excavating in all kinds of dry and moist wood. While they are most abundant in the trunks, limbs, and roots of trees, one species at least also infests the cones, a few are even leaf miners, and still others are gall-makers.

This large family consists of no less than 8,000 species. It reaches its greatest development in the tropical and subtropical regions but is also well represented in the cooler regions wherever forests occur.

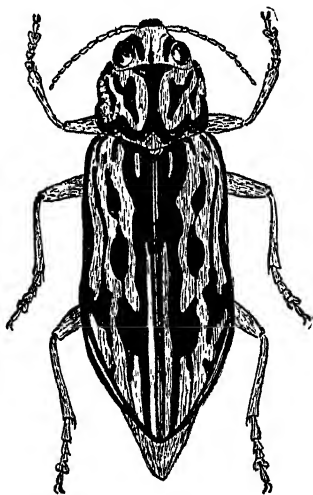


FIG. 186. The sculptured pine beetle, *Chalcophora angulicollis* (LeConte), a buprestid common to the pine forests of western North America.

Some of the more important and interesting genera and species arranged alphabetically are:

Acmæodera Eschscholtz. Medium-sized species wide anteriorly and pointed posteriorly; dark with brilliant yellow and red bands and spots on the dorsum. Adults commonly taken on flowers.

Agrilus Curtis. Small, slender species of which there are no less than 15 important world species especially injurious as girdlers to deciduous ornamental and forest trees and shrubs.

Buprestis Linn. A large family of medium-sized species containing at least 20 species of economic importance to forests in North America. *B. aurulenta* Linn., 14–19 mm. long and iridescent green, gold, and copper, is a common North American species attacking chiefly pine, but it also breeds in cedar, spruce, and fir.

Chalcophora Solier has large sculptured and calloused, bronzy, metallic species which attack chiefly pines but also feed upon other conifers. *C. marina* (Linn.), 24–30 mm. long, is the common European species, and *C. angulicollis* (Lec.) 25–28 mm. is North American. The adults fly with a loud humming noise.

Chrysobothris Eschscholtz is a large genus which includes at least 25 North American species injurious to deciduous shrubs and trees under cultivation and in the forests. Of these the flat-headed apple tree borers, *C. femorata* Olivier and *C. mali* Horn, are the most important.

Chrysochroa Solier comprises many brilliant metallic species in the tropical and subtropical regions including those referred to above.

Chrysophana placida (Lec.), metallic green, 10–18 mm. long, not only breeds in many kinds of coniferous trees but has the distinction of being the only known North American species living in pine cones.

Dicerca Eschscholtz includes a large number of bronzy species having the tips of the elytra constricted and elongated. They feed upon a large number of deciduous and coniferous shrubs and trees throughout the north temperate regions.

Melanophila Eschscholtz, small flat dark metallic species often with yellow spots on the elytra. There are 12 species which are of importance to coniferous forests in North America. The smoke beetle, *M. consputa* Lec., 8–13 mm., black with 12 small yellow elytral spots, is attracted by forest fires and smelter plants and often severely bites the workmen in logging camps and about mills and mill ponds in the Pacific states. The Australian fire beetle, *Merimna atrata* Laporte and Gory, is attracted to brush fires and lights, according to Tillyard (1926).

Stigmodera Eschscholtz is the dominant genus in Australia with more than 300 species, many of them large and all beautifully colored. Among them are the beautiful jewel beetles, *S. ræi* Hope, and *S. gratiosa* Chevrolat, both deeply pitted, brilliant green, and glowing like jewels and both being set in mountings and used as jewelry (Tillyard 1926).

X. Superfamily DRYOPOIDEA Leng 1920

Family DRYOPIDÆ (Erichson 1847) Leng 1920 (= PARNIDÆ Leach 1817, Stephens 1929).

Small, pubescent and hairy subaquatic and aquatic beetles that occur in wet places and in water. The adults carry air on the bodies and crawl about rather than swim. The larvæ of *Dryops* Olivier live under stones. They are cosmopolitan. The members of related family PSEPHENIDÆ LeConte 1862 are aquatic and have remarkable disk-like larvæ that attach themselves to stones in swift-flowing streams, rapids, cascades, and waterfalls. The genus *Psephenus* Haldeman occurs in North America and Asia.

XI. Superfamily DASCILLOIDEA Reitter 1906

KEY TO IMPORTANT FAMILIES

1. Front coxæ transverse, subcylindrical 2
 Front coxæ globular or conical 3
2. Legs stout, retractile; front coxæ open behind; hind coxæ extending to the margin of the body; tibiæ dilated, usually with a groove near the apical end for the reception of the tarsi; tibial spurs distinct; last tarsal segment small and quadrate. Small to medium convex beetles. (Pill Beetles.) BYRRHIDÆ p. 560
 Legs normal, tibiæ slender, spurs reduced or absent; front trochantins present; antennæ serrate, 11-segmented, inserted below a slight ridge in front of the eyes; claws simple or pectinate. Small to medium terrestrial and aquatic beetles. (Soft-bodied Plant Beetles.)
 DASCILLIDÆ
3. Front coxal cavities closed behind; plate of hind coxæ weak. Small oval, pubescent beetles found in flowers BYTURIDÆ p. 560
 Front coxal cavities open behind; plate of hind coxæ distinct. Small convex scaly beetles usually feeding on dead or dry animal matter. (Skin or Larder Beetles.) DERMESTIDÆ

Family DERMESTIDÆ (Gyllenhal 1808, Leach 1815) Samouelle 1819 (Dermes'ti-dæ, from the Greek *δέρμα*, skin, + *εσθω*, to devour, to eat; referring to the eating of skins by these beetles). German, Speckkäfer, Pelzkäfer. French, Dermestidés. Skin Beetles, Hide Beetles, Tallow Beetles, Dermestids.

Small to medium-sized, oval, hemispherical or elongate, cylindrical beetles; dull and somber-colored, often mottled; smooth or usually clothed with scales and hairs. Head small, partially hypognathous. Antennæ short, clavate and often clubbed, 11-segmented, resting in a groove under the prothorax, club one- to three-segmented. Eyes well developed. A single ocellus on the frons in all forms excepting *Dermestes*. Wings normally well developed for flying. Legs short, folding close to body; fore coxæ long, oblique, contiguous; hind coxæ re-

ceive the femora; tibiae sometimes with spurs; tarsi five-segmented; claws simple. Larvæ caraboid, densely covered with long and short hairs which may be arranged in a number of whorls or tufts. They have short antennæ and six ocelli on each side.

The larvæ and adults feed extensively upon dead animal and plant materials including skins, horn, hair, wool, tallow, cured meats, cheese, museum insect specimens, and cereals and cereal products. They are pestiferous in manufacturing establishments, warehouses, stores, and repositories for animal products of any kind and are of great concern also to museums of natural history and to the housewife. Because of them stuffed animals are treated with arsenic or some similar poisons; insect specimens are housed in insect-proof cabinets and regularly fumigated; furs are kept in cold storage; and the woolen clothes and carpets must be carefully guarded against spoliation.

The adults often occur in large numbers out of doors, and many species visit flowers, especially umbelliferous and lilaceous forms. Not all species fall in the category of injurious insects.

The family is a relatively small one consisting of but 34 genera and approximately 550 species. A number of species were early widely and generously distributed by whaling and hide and tallow ships as well as by general commerce. The important genera are:

Dermestes Linn., 53 spp. (cosmopolitan). Three species, *D. cadaverinus* Fab., *D. lardarius* Linn., and *D. vulpinus* Fab., are cosmopolitan and quite destructive. They average from 7–9 mm. in length and are variously colored black and whitish. The last named species has been employed by museums to clean the dried flesh from bones.

Attagenus Latr., 87 spp. (Holarctic, Ethiopian). Two species, *A. pello* Linn., 4.0–5.5 mm., and *A. piceus* Olivier, are widely distributed and of economic importance. *Megaloma* Herbst, 10 spp. (Palæarctic, Australian). *Trogoderma* Latr. 81 spp. (nearly cosmopolitan). *Anthrenus* Fab., 65 spp. (cosmopolitan). It contains two serious pests, *A. scrophulariæ* (Linn.) and *A. verbasci* (Linn.), both cosmopolitan and serious museum and household pests. The former is mottled brown and white, 3.0–4.5 mm. long, and the latter is varicolored and 1.8–3.2 mm. in length.

Family BYTURIDÆ Thomson 1859.

A small family related to the DERMESTIDÆ which is of interest because of the economic berry-infesting species including *Byturus æstivus* (Linn.) and *B. tomentosus* (Fab.) of Europe and *B. unicolor* Say of North America. Raspberries are injured most by them.

Family BYRRHIDÆ Erichson 1846.

Pill Beetles. Small or minute, shining, black, hemispherical or oval convex, hard beetles which occur in moss and under logs, bark, stones, debris, and in the soil. *Amphicyrtia dentipes* Erichson of California lives in the soil, and the shining small dark-brown or black larvae, 10 mm. long, are often injurious to

wild and cultivated plants. The largest species in the family is *Byrrhus gigas* Fab. of Europe, which is 11.5–13.0 mm. long. The family has about 500 species and is well represented in Europe and North America.

XIII. Superfamily CUCOJOIDEA Sharp 1912

KEY TO IMPORTANT FAMILIES

1. Tarsi three-segmented 2
Tarsi four- or five-segmented 3
2. Tarsal claws simple; mesepimeron quadrangular; first abdominal sternite without coxal lines. Oblong or suboval, brightly colored beetles, mostly living in fungi **ENDOMYCHIDÆ** p. 565
Tarsal claws dilated or toothed at base; mesepimeron triangular; first abdominal sternite with arcuate coxal lines. Small oval predacious beetles. (Ladybird Beetles.) **COCCINELLIDÆ** p. 566
3. Tarsi five-segmented, rarely heteromerous 4
Tarsi four-segmented; first three or four abdominal sternites fused; antennæ 10- to 11- or rarely eight-segmented, terminating in a one- or two-segmented club; front and middle coxæ small and globular, hind coxæ transverse. Small elongate or cylindrical bark or ground beetles. (Cylindrical Barkbeetles.) **COLYDIDÆ**
4. Front coxæ transverse 5
Front coxæ not transverse 6
5. Tarsi more or less dilated, first segment not shortened; fourth segment very small; elytra truncate, not usually extending to the tip of the abdomen. (Sap-feeding Beetles.) **NITIDULIDÆ** (in part) p. 562
Tarsi slender, the first segment very small; elytra never truncate, always covering abdomen. Small to medium, usually flattened beetles living under bark or inhabiting granaries. (Grain- and Bark-gnawing Beetles.) **OSTOMATIDÆ**
6. Front coxæ globose, closed behind; tarsi dilated and hairy, fourth segment very small; antennæ 11-segmented, the last three or four segments forming a club; elytra entire; head immersed into the thorax almost to the eyes. Small to medium-sized red and black beetles. (Pleasing Fungus Beetles.) **EROTYLIDÆ** p. 563
Front coxæ oval 7
7. Middle coxal cavities not closed on the outer side by the union of the meso- and metasterna; tibiæ with two spurs; antennæ 11-segmented; elytra covering abdomen. Small, very flat black, brown, or reddish beetles often living under bark. (Flat Barkbeetles.) **CUCUJIDÆ** p. 563
Middle coxal cavities closed by the sterna; prosternum prolonged; front coxal cavities open behind; antennæ 11-segmented with loose club. Very small oval or elongate, flat, pubescent, punctate, and often yellow or brown beetles. (Silken Fungus Beetles.) **CRYPTOPHAGIDÆ** p. 565

Family OSTOMATIDÆ Ganglbauer 1899 (Os'to-mat'i-dæ, from the Greek *οστούν*, bone; application uncertain). Gnawing Beetles.

Small to medium-sized, elongate, slender, cylindrical or flattened, or hemispherical beetles which are usually smooth and shiny or punctured, rugose, or

striated. The colors are somber or brilliant metallic. Head prognathous, small, elongated, free or partially withdrawn into the prothorax. Antennæ small, slender, clavate — the apical segments usually expanded laterally, 11-segmented. Eyes small. Mandibles often large and strong. Prothorax long and narrow or wide and flattened. Legs short. Hind coxæ contiguous. Tarsi five-segmented, first very small, fifth long.

Larvæ are caraboid or somewhat cylindrical with strong mouth parts, well-developed legs, and a pair of terminal chitinated hooks. They are quite active and dangerous looking and are frequently mistaken for larvæ of neuropteroid insects.

These beetles are largely predacious and occur under the bark of trees, in refuse, litter, fungi, and stored cereals and cereal products. They are chiefly temperate, subtropical, and tropical and comprise some 650 species.

The best known species is the cosmopolitan *Cadelle*, *Tenebrioides mauritanicus* (Linn.), brownish-black, 6–10 mm. long, which commonly occurs in cereals. The larvæ are predacious on the immature forms of grain beetles and moths and are believed also to feed upon the cereals. The beautiful metallic blue-green *Temnochila cærulea* Olivier, 11–18 mm., of Europe, and *T. virescens* (Fab.), 10–13 mm., of North America are common under the bark of coniferous and other trees.

Family NITIDULIDÆ (Leach 1815) Stephens 1830 (Nit'i-dul'i-dæ, from the Latin *nitidus*, bright, lustrous, shining; from the shiny appearance of certain adults). Nitidulid Beetles.

Minute to small, rather broad and flattened beetles, often with the elytra shortened so as to expose the last two segments of the abdomen; shining and smooth or hairy, pubescent, or punctate; somber-colored, black or brown, spotted, or variegated, some brilliant and metallic. Head comparatively large. Eyes large. Antennæ short, clavate, 11-segmented. Prothorax usually wider than long. Legs short; coxæ cylindrical, separated; tibiæ sometimes dilated; tarsi five-segmented, the fourth segment smallest. Elytra longer or shorter than the abdomen. Abdomen with five visible sternites. The larvæ are caraboid and quite active, often with a pair of apical chitinated processes.

These beetles are largely saprophagous in both the larval and adult stages, feeding upon decayed or dried vegetable matter. They occur in fruit and garbage dumps, in cereals, dried fruits, under bark of dead trees, in galleries of wood-boring beetles, and in ants' nests. Certain species may consume pollen and living plant tissues. The family is cosmopolitan and consists of some 2,500 species.

The minute European pollen or blossom beetle, *Meligethes æneus* Fab., greenish bronze and 1.5–2.7 mm. long, is of economic importance. The eggs are laid in the buds and flowers of cruciferous plants, and the larvæ, largely pollen eaters, do some good as pollenizers. The adults feed on and may destroy the flowers of cruciferous and umbelliferous plants. The dried fruit beetle, *Carpophilus hemipterus* (Linn.), of various shades of brown, 2–4 mm. long, and

C. dimidiatus (Fab.), all dark brown, 2.0–3.5 mm., are cosmopolitan and commonly occur on decaying vegetation and fruits, but are also destructive to dried fruits and cereals in storage. The genera *Amphotis* Erichson and *Nitidula* Fab. are common in the temperate regions. *N. bipunctata* Linn., 3–5 mm., is a general feeder on vegetable and animal matter in Europe and North America.

Family CUCUJIDÆ (Leach 1815) Stephens 1829 (Cu-cu'ji-dæ, from the Latin *cucujus*,¹ a golden-green beetle of South America). Cucujid Beetles.

Minute to small, narrow, elongated, flattened beetles, some of them being thin as paper and living under the bark of trees. They are smooth, punctate or striate and variously colored brown, reddish, and yellowish. The head is well developed. Antennæ long, filiform, moniliform, or clavate with long scape; 11-segmented. Mandibles prominent, strong. Tarsi four- to five-segmented. Some of the males have the formula 5-5-4. Larvæ cylindrical or flat, distinctly segmented, with well-developed legs and with cerci and urogomphi often present. All forms live under bark, in dead wood, litter, cereals and cereal products, dried fruits, and on dried plant materials.

The family is a small one, consisting of about 920 species widely distributed. The important genera are *Cucujus* Fab., 12 spp. (Holarctic) and *Læmophilæus* Castelnau, 321 spp., both of which occur under bark and some of which are destructive to dried fruit and cereals; *Silvanus*² Latr., 55 spp. (cosmopolitan); *S. unidentatus* Fab., the most widely distributed species; *Oryzæphilus* Ganglbauer, 8 spp. (all cosmopolitan). The minute brown sawtoothed grain beetle, *O. surinamensis* (Linn.), 3 mm. long, the most widely distributed and destructive member of the order, is characterized by the row of marginal teeth on each side of the prothorax. It is particularly destructive to cereals, dried fruits, nuts, seeds, and products made therefrom. *Cathartus* Reiche, 4 spp. (cosmopolitan), has several cereal-feeding species including *C. advena* (Waltl.) and *C. quadricollis* Guérin, both distributed through commerce.

Family EROTYLIDÆ (Leach 1815) Samouelle 1819 (Er'o-tyl'i-dæ, from the Greek ἐριον, wool, + τύλος, lump, knot; referring to their pubescent bodies or the fungi upon which they feed). Pleasing Fungus Beetles.

Small to medium-sized, elongated or almost spherical beetles which are smooth or hairy and usually dull or metallic blue or green. Head small. Antennæ inserted in front of or between the eyes; 11-segmented; club large and three- to four-segmented. Fore and middle coxæ globose. Tarsi five-segmented; the three basal ones wide and pad-like and pubescent; the fourth very small. Abdomen with five visible sternites. Larvæ variable; flattened; with or without cerci or urogomphi. Living in the soil, in stems of plants, and on fungi. One of the smallest species is *Cryptophilus integer* Heer, a reddish, hairy European

¹ The Spanish used the name "cucujo" for the luminous elaterid beetle, *Pyrophorus noctilucus* (Linn.) (see p. 555).

² This genus is now placed in the family SILVANIDÆ LeConte 1862 by some recent workers.

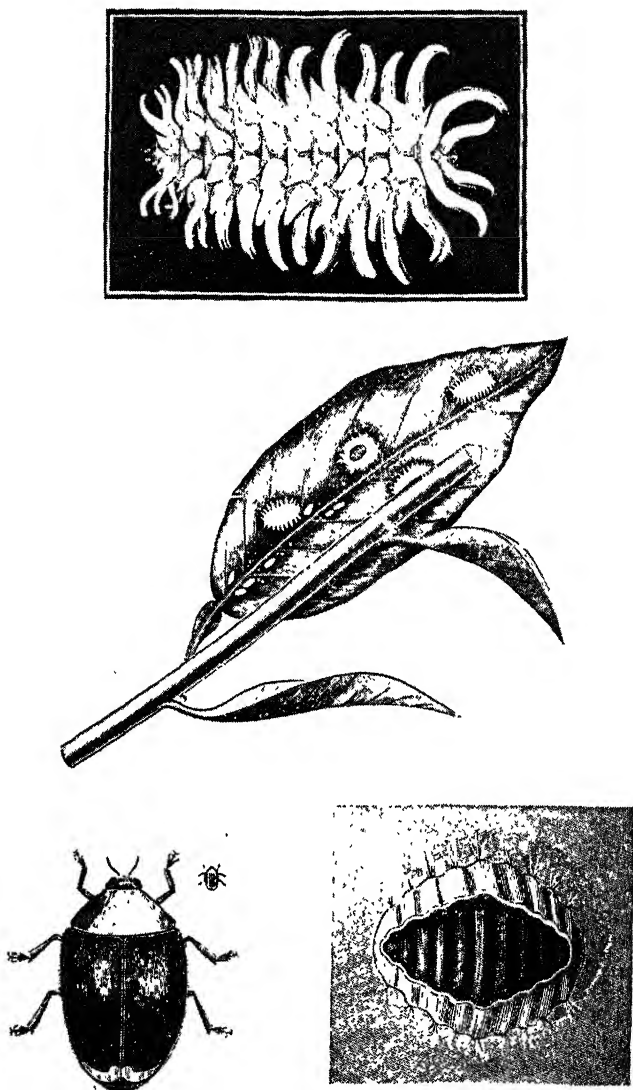


FIG. 187. The mealybug destroyer, *Cryptolæmus montroussieri* Mulsant, an Australian ladybird beetle extensively employed in the biological control of mealybugs in many parts of the world. Larva, larvæ and mealybugs on orange leaf, adult, and pupa. The larvæ resemble large mealybugs. (After California State Board of Horticulture, 1899, from *A History of Entomology*.)

species only 2.0–2.3 mm. long, and what appears to be one of the largest species is *Esiscaphula hercules* Lea, 23 mm. long, in Australia.

This is a medium-sized family containing some 2,600 species which reach their greatest development in the tropics but are also well represented in the temperate regions.

The important genera in the temperate regions are *Anchicera* Thomson, *Dacne* Latr., *Languria* Latr., *Megalodacne* Crotch, *Triplax* Herbst, and *Tritoma* Fab.

The clover stem erolytid, *Languria mozardi* Latr., narrow, 5–6 mm. long, reddish and dark blue, is a pest of economic importance because of the injury to lettuce, clover, and alfalfa in western North America.

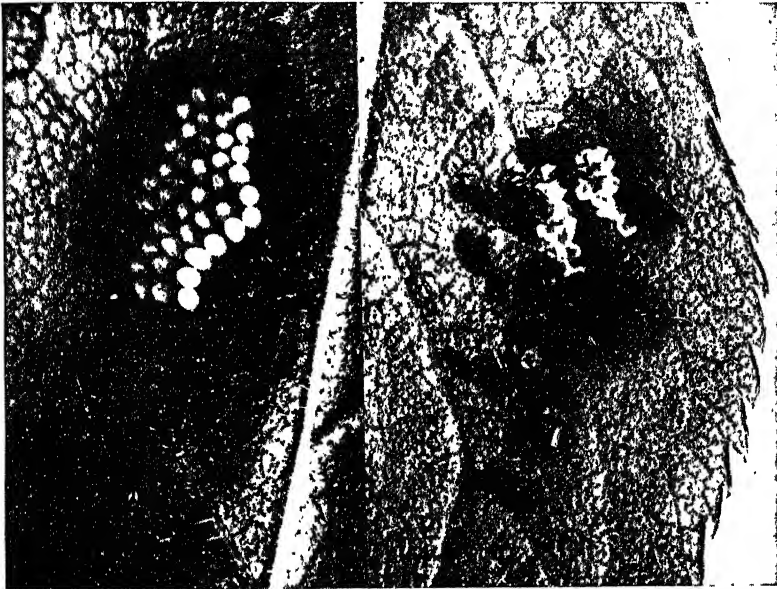


FIG. 188. Eggs and newly-hatched larvæ of the convergent ladybird beetle, *Hippodamia convergens* Guérin. (From *Insects of Western North America*.)

Family CRYPTOPHAGIDÆ Thomson 1863.

Silken Fungus Beetles. Minute to small elongated pubescent species living on fungi, decaying organic matter, and in the nests of ants and wasps where they are no doubt scavengers. Some visit flowers and plants. The members are widely distributed throughout the world, and are specially well represented in the Holarctic region. About 800 species are known.

Family ENDOMYCHIDÆ (Leach 1815) Samouelle 1819 (En'do-mych'i-dæ, from the Greek ἐνδον, in or within, + μύκης, fungus; from their living in fungi). Fungus Beetles.

Minute, small, to medium-sized, 1–25 mm. in length; smooth or somewhat spined. Colors striking red and black, somewhat resembling chrysomelid and

ladybird beetles; tropical forms specially brilliant. Head small. Antennæ long, inserted between the eyes and with a flattened, three-segmented club. Mouth parts small. Coxæ: fore and middle pairs globose. Tarsi four-segmented, third segment minute. Abdomen with five or six visible sternites, first longest. Larvæ curled, blind, short, smooth or hairy, some armored; antennæ well developed. These insects feed upon fungi, dung, dead wood, and refuse of wine, vinegar, and fruit canning and drying establishments. The family is cosmopolitan and has about 950 species. The most important genera are *Aphorista* Gorham, *Mycetina* Mulsant, *Epipocus* Germar, *Rhymbus* Gerstaecker, and *Endomychus* Panzer.

Family COCCINELLIDÆ Latreille 1807 (Coc'ci-nel'li-dæ, from the Greek *kókkinos*, scarlet; referring to the color of the adults of some species). German, Marienkäferchen, Sonnenkälbchen. Ladybirds, Ladybird Beetles, Coccinellids.

Minute to small, oval or circular, convex or hemispherical beetles with horizontal ventral surface; smooth, shiny or pubescent surface; somber, black,

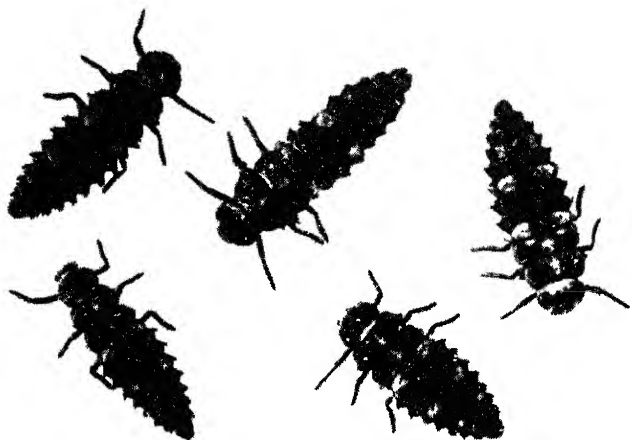


FIG. 189. Larvæ of the convergent ladybird beetle. (From *Insects of Western North America*.)

brown, gray, or brightly and brilliantly enameled or metallic, often spotted, variable within a species and different in the sexes. Head small, partially withdrawn into prothorax or concealed under the pronotum. Eyes large. Antennæ short, clavate, mostly 11-segmented. Mandibles simple, with basal tooth and apices bifid in predacious species, and without basal tooth and with multi-toothed apices in herbivorous species. Prothorax prominent but usually narrower than the abdomen. Wings normally well developed for flight. Elytra covering the body. Legs short, stout; tarsi four-segmented, first and second dilated and pubescent underneath, third very small; claws, one pair, usually

toothed. Abdomen with five or six free sternites. Larvæ caraboid, somber, or sometimes with bright markings; rugose, spiny, wrinkled, hairy, and certain species covered with cottony wax; antennæ minute and with as many as five segments; three to four ocelli on each side; mandibles curved, with or without basal molars.

The ladybirds are among the best known and most loved of all insects, and many of the common red and red-and-black-spotted forms have long been revered and regarded as omens of good luck. The adults are active crawlers and fliers and are often very abundant throughout the spring, summer, and autumn periods. The great majority feed to some extent upon plant exudations, nectars, and particularly upon small soft-bodied insects, including especially aphids and coccids, and are therefore considered beneficial.



FIG. 190. The adults of the convergent ladybird beetle assembling near a stream in the Sierra Nevada Mountains, California, in autumn preparatory to entering hibernating quarters among the leaves and debris nearby.

The family, a fairly large one, consists of 247 genera and about 3,000 species. Some of the smallest species are the European *Clitostethus arcuatus* Rossi, 1.2–1.5 mm., and the American *Stethorus picipes* Casey, 1.0–1.3 mm. in length, while the largest species are *Anatis ocellata* (Linn.), 8–9 mm., of Europe, *Anisolemnia dilatata* (Fab.), 11.2 mm., and *Synonycha grandis* Thunberg, 13.6 mm., both of southern Asia and Malaysia.

The larvæ and adults when disturbed may discharge what is thought to be a protective fluid.

PHYTOPHAGOUS SPECIES

Members of the genera *Halysia* Muls., 14 spp. (Holarctic); *Psyllobora* Chevrolat, 44 spp. (North and South American); *Thea* Muls., 12 spp. (Palæarctic, Ethiopian, Indo-Malysian); and *Vibidia* Muls., 3 spp. (Palæarctic), feed on fungi or pollen. Members of the large genus *Epilachna* Redtenbacher, 466 spp.,

are cosmopolitan in distribution and are plant feeders. Some of them are very serious pests of agricultural crops. Among these may be mentioned the following species: *E. argus* (Geoffroy) and *E. chrysomelina* (Fab.) (Palæarctic); *E. 28 maculata* Motschulsky (Oriental-Australasian), *E. canina* (Fab.) and *E. fulvosignata* Reiche (Ethiopian); *E. borealis* (Fab.) (North and South American) and *E. varivestris* Muls. (*corrupta* Muls.) (North American).

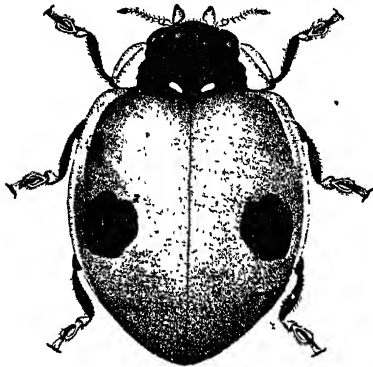


FIG. 191. The two-spotted ladybird beetle, *Adalia 2-punctata* (Linn.). (From *Insects of Western North America*.)

PREDACIOUS SPECIES

Hyperaspis Redtenb., 335 spp. (Holarctic, Neotropical, Oriental, Ethiopian). *H. campestris* Herbst and *H. reppensis* Herbst (European and Asiatic); *H. signata* Olivier (North American). Effective predators on coccids. *Brachyacantha* Chevrolat, 48 spp. (North and South American). *Stethorus* Weise, 13 spp. (Holarctic, Ethiopian, Malaysian). *S. punctillum* Weise (Palæarctic). *S. punctum* (North American). Effective predators of mites, aphids, and coccids. *Scymnus* Kugelann, 574 spp. (Holarctic, Neotropical, Indo-Malaysian, Ethiopian). *S. bipunctatus* Kugel., *S. frontalis* (Fab.), *S. interruptus* Goeze (Palæarctic). Predacious on aphids and coccids. *Cryptolæmus* Mulsant, 7 spp. (Australian). *C. montrousieri* Mulsant, the effective predator of mealybugs, has been widely distributed by man. *Rodolia* Muls., 41 spp. (Indo-Malaysian, Australian, Madagascan). The *vedalia*, *R. cardinalis* Muls., is an effective predator and check on the cottony cushion scale and now widely distributed from its native Australia to many parts of the world by man. It is probably the most famous member of the family.

Rhizobius Stephens, 76 spp. (Palæarctic, Malaysian, Australian, Madagascan). *R. liturata* (Fab.) (European), and *R. ventralis* Erichson (Australian and introduced into California). Predators on coccids. *Ceratomegilla* Crotch, 5 spp. (North and South American) has one important species, *C. maculata* (De Geer), which occurs throughout the New World and is an aphid feeder.

Hippodamia Muls., 21 spp. (Holarctic). *H. 7-maculata* (De Geer), and *13-punctata* (Linn.) are distributed throughout Europe and northern Asia, and the latter also extends into North America. *H. convergens* Guérin is a very common species in North America which hibernates in the mountains of the western states. Members of this genus are chiefly aphid predators.

Coccinella Leach, 82 spp. (cosmopolitan). *C. axiridus* Pallas, *C. hieroglyphica* Linn., *C. 4-punctata* Pontoppidan, *C. 7-punctata* Linn., *C. 11-punctata* Linn. are all Palæarctic. *C. transversoguttata* Falderman and *C. trifasciata* Linn. range across northern Asia and North America. They are mostly feeders on aphids and other small insects. *Adalia* Muls., 28 spp. is cosmopolitan owing

to the very wide distribution of the two-spotted ladybird, *A. 2-punctata* (Linn.), which occurs throughout the world and feeds upon aphids and related insects. *Cycloneda* Crotch, 42 spp. (North and South American), is represented by *C. sanguinea* (Linn.) the commonest species. *Exochomus* Redtenb., 62 spp.

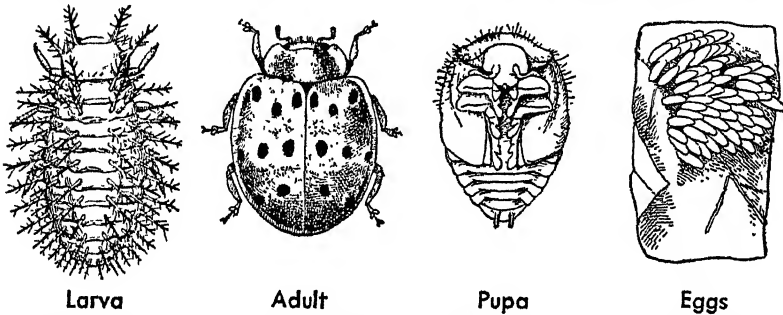


FIG. 192. The Mexican bean beetle, *Epilachna varivestris* Mulsant. (After Chittenden, U.S.D.A.)

(Holarctic, Neotropical, Ethiopian). *E. 4-pustulatus* (Linn.) and *E. flavipes* Thunberg are important Old World species.

XIV. Superfamily MORDELLOIDEA Leng 1920

KEY TO IMPORTANT FAMILIES

1. Head strongly constricted behind the eyes; tarsal claws sometimes pectinate 2
 Head gradually narrowed behind the eyes; tarsal claws simple or cleft; middle coxæ prominent, contiguous. Slender, soft-bodied beetles
CEDEMERIDÆ
2. Sides of prothorax with sharp lateral margins, the base as wide as the elytra; antennæ filiform, 11-segmented; head joined vertically against the thorax; hind coxæ flat; elytra soft; tip of abdomen prolonged into a point. (Tumbling Flower Beetles.) . . . **MORDELLIDÆ** p. 570
 Sides of prothorax rounded and without sharp lateral margins . . . 3
3. Hind coxæ normal; tarsal claws simple; antennæ filiform, 11-segmented, inserted before the eyes at the sides of the front; middle coxæ with trochantins. Medium to small ant-like beetles. (Ant-like Flower Beetles.) . . . **ANTHICIDÆ**
 Hind coxæ large and prominent; tarsal claws cleft or toothed, head deflexed, front vertical; antennæ 11-segmented, inserted at the sides in front of the eyes; elytra soft and entirely or only partly covering abdomen. Medium to large soft-bodied beetles. (Blister Beetles.)
MELOIDÆ p. 570

Family CEDEMERIDÆ Thomson 1859.

A small family of 800 species with soft bodies; slender; somber or brightly colored and metallic. The adults commonly visit flowers, and many are crepus-

cular and nocturnal. The larvæ of a number of species including *Calophus angustus* Lec. and *Nacerda melanura* (Linn.) breed in dead coniferous timbers. The latter has become quite injurious to lower, shaded, and damp timbers of wharves along the California coast. *Copidita 4-maculata* (Mots.) breeds in old wet mine and bridge timbers in California.

Family MORDELLIDÆ (Leach 1815).

Tumbling Flower Beetles. A large family of small beetles; characterized by laterally compressed, arched, silky bodies pointed posteriorly and extending beyond the tips of the elytra; long legs; and jumping and tumbling reactions when disturbed. The adults are common on flowers. There are about 800 species distributed throughout the world.

Family MELOIDÆ Thomson 1859 (Me-lo'i-dæ, from the new Latin *Meloë*; origin uncertain). German, Pflasterkäfer, Ölkafer, Maiwürmer. French, Meloides. Blister Beetles, Oil Beetles, Meloids.

Medium-sized, elongated, somewhat cylindrical or robust, soft-bodied beetles which are characterized in some species by having short, loosely connected elytra. Smooth, rugose, sculptured, punctate, pubescent, or hairy. Colors mostly somber — black, gray, brownish, or tan — or bright, with metallic iridescences. Some species are beautifully sculptured, brilliantly colored, and grotesquely formed. Head hypognathous, large, free, constricted at base. Eyes large, widely separated. Antennæ setiform or certain segments enlarged in males; 11-segmented. Mouth parts well developed. Prothorax small, usually not much wider than the head, much narrower than rest of thorax, and scarcely longer than wide. Wings well developed, abortive, or absent. Elytra longer or shorter than the body, not closely joined in the middle, even overlapping, and widely divergent apically. Legs long and slender. Tarsi long, five-segmented. Anterior and middle coxæ large and contiguous. Abdomen often with the posterior segments exposed and with six visible sternites.

These beetles have a complex development known as hypermetamorphosis. The very minute eggs are laid in great numbers in masses in the soil. The newly hatched young, called primary larvæ or triungulins, are minute and campodeiform with well-developed legs, antennæ, and cerci. They are very active and seek out egg masses or brood chambers of ground-nesting insects, or they may actually attach themselves to certain adult hosts and ride to the nests or brood chambers of the latter. Here they feed upon the honey or food stored for the host larvæ or are predacious upon the latter. But very shortly they transform into apodous, sluggish, scarabæoid type of larvæ and remain until fully developed, passing, in some cases, into still a third type of larvæ and into a prepupa, a pupa, and finally into an adult.

The charming sketch by Fabre (1857) describes the life history of the European *Sitaris muralis* Förster, a small black and yellow beetle 8–10 mm. long which develops in nests of bees belonging to the genus *Anthophora*. The eggs are laid near the ground nests of the bees during late summer and hatch in the

fall. The larvæ hibernate and become active the following spring, climb the plants to the flowers, and await the visits of the female host bees to which they attach themselves to be carried to the nests being constructed by the bees in the soil. Upon arrival there the triungulins leave the adult bees to seek out their eggs, which are consumed and which enable the predators to transform into apodous eruciform larvæ. These latter consume the stored honey, which enables them to develop fully and to transform into prepupæ which hibernate the second winter. The following spring pupation takes place and the adult

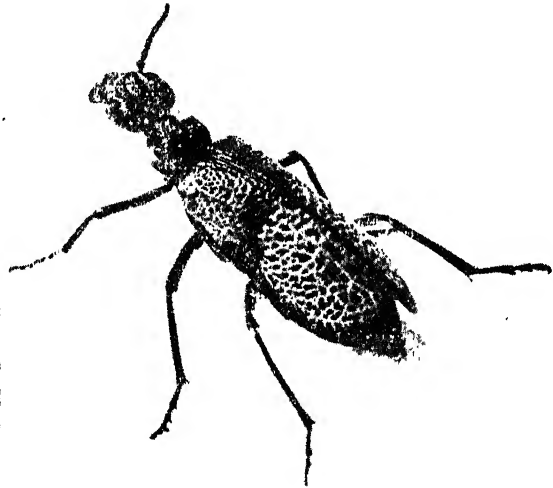


FIG. 193. The soldier beetle, *Tegrodera erosa* Casey, of western North America. (From *Insects of Western North America*.)

beetles emerge in the summer of the second year preparatory to mating and laying their eggs as indicated above.

There are similar complicated life histories of many species in this most unique group. The adults are normally plant feeders and are often very serious agricultural pests while their larvæ may be beneficial by destroying the eggs of grasshoppers and other orthopteroid insects. In the genus *Epicaula* there are about 20 well-known species in which the adults are injurious. Members of all the other genera may also be rated as pests.

Throughout the ages certain of these beetles have yielded cantharides, a preparation of parts of the dried beetles, and cantharidin, a crystalline solid chemical which has been used medicinally as an aphrodisiac, a vesicator, and a diuretic. The cantharidin is obtained from the dried bodies but is abundant in the elytra although the eggs and ovaries are richest in the chemical. The most important use has been as a vesicator. When applied to the human skin rubefa-

cient action occurs resulting in blisters. It is also of some value as a counter-irritant. Internal doses have often produced very serious results and even death.

The telini fly, *Mylabris cichorii* (Linn.), *M. sidae* (Fab.), and *M. phalerata* (Pallas), Old World species occurring throughout southern Asia and eastern Europe, have been an important source of cantharidin. But the most important species is the so-called Spanish fly, *Lytta vesicatoria* (Linn.) (*Cantharis*), a beautiful iridescent green and blue species 12–21 mm. long which is common to much of Europe. The adults feed chiefly on ash and privet. *Epicauta hirticornis* (Haag-Rutenberg) of India is said to be richest in cantharidin.

The family is cosmopolitan in distribution and comprises no less than 2,300 species. Many genera inhabit semiarid and desert regions where they have become peculiarly adapted to their surroundings. Among the most important genera are *Epicauta* Redtenbacher, 247 spp. (cosmopolitan, except Australia); *Lytta* Fab., 177 spp. (Holarctic, Neotropical); *Meloe* Linn.: 133 spp. (Holarctic, Ethiopian); *Mylabris* Fab., 376 spp. (cosmopolitan except Australia); and *Zonitis* Fab., 137 spp. (cosmopolitan except for South America).

XV. Superfamily TENEBRIONOIDEA Seminov 1902

Family TENEBRIONIDÆ (Leach 1815, 1817) (Te-neb'ri-on'i-dæ, from the Latin *tenebrio*, one who loves darkness; referring to the nocturnal and secluded habits of these beetles). German, Schwarzkäfer. Darkling Ground Beetles, Tenebrionid Beetles, Pincate Beetles.

Small to large, normal or robust, elongated, somewhat flattened, or cylindrical hard beetles which are smooth, rugose, punctate, sculptured, tuberculate, striated, or hairy. They are mostly black, dust-colored, or reddish-brown, but some species are marked with light colors and tropical forms may even be brilliant. Head relatively small or narrow and fitting into the prothorax, mouth parts well developed with large mandibles. Antennæ arising under the sides of the head, simple, clavate, moniliform, short, 11-segmented. Eyes prominent; horn-like processes may be present in some males. Prothorax variable in size and form and may be much narrower or wider than the mesothorax. Legs stout, often long and smooth, spined or dentate; tarsi heteromorous with 5-5-4 formula, may be dilated in males; claws simple. Wings developed for flight in comparatively few species; normally absent or vestigial. Elytra usually covering abdomen and fused down the middle in many species. Abdomen often large, with five visible sternites; some males with tuft of hair. Larvæ cylindrical, chitinous or leathery; white, yellow, or brownish; distinctly segmented; with two terminal abdominal hooks and a short retractile organ. Commonly called "false wireworms" because of their resemblance to wireworms. Pupæ may possess short cerci.

These beetles are readily distinguished by their nocturnal habits (some diurnal), death feigning, slow awkward gait, strong offensive odors, and the habit of certain large species of standing with the abdomen raised vertically into the air. They are largely phytophagous scavengers and feed mostly on dead and decay-

ing vegetable matter, dung, or on cured seeds, cereals, cereal products, and to some extent on fungi and other living plants. Some are ant guests. They are often prevalent in arid and desert regions and may multiply to such an extent as to swarm over large areas, at which times they may devastate natural vegetation and agricultural crops.

The well-known mealworm, *Tenebrio molitor* Linn., brown and 15-16 mm. long, is a pest of cereals and cereal products in granaries, mills, and storehouses the world over. The larvæ of the mealworm are reared in enormous numbers to feed birds and confined animals and form a commercial product of considerable

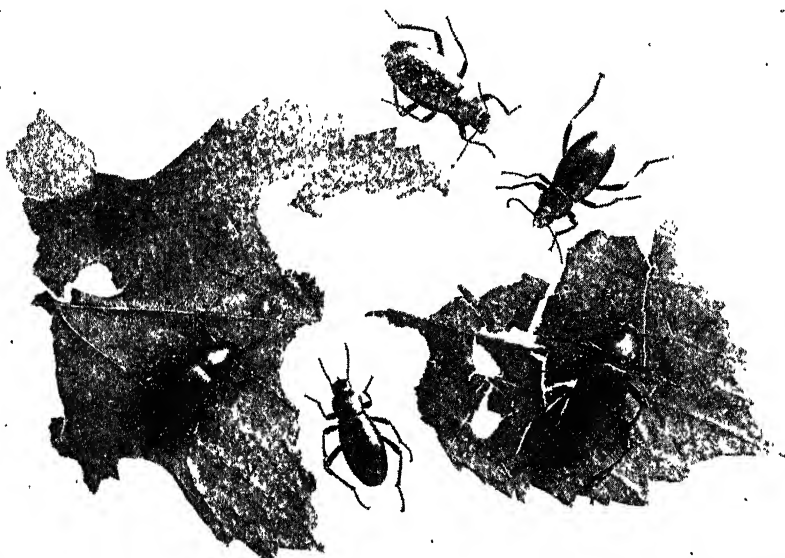


FIG. 194. The tenebrionid beetle, *Eleodes femorata* LeConte, of California. (From *Insects of Western North America*.)

value. The broad-horned flour beetle, *Gnathocerus cornutus* (Fab.), the red flour beetle, *Tribolium ferrugineum* (Fab.), and the confused flour beetle, *T. confusum* Duval, are small species with similar habits and likewise widely distributed by commerce. Other genera injurious to cereals are *Hypophlaeus* Fab., *Latheticus* Waterhouse, and *Palorus* Mulsant, of eastern Asia. They also occur in other regions. The members of the large North American genus *Eleodes* Eschscholtz, 123 species, which is the most characteristic group in North America, are mostly smooth black beetles attaining large size and are often destructive to growing plants. Members of the genera *Embaphion* Say of North America, *Apatrum* Fab. of Europe, and *Gonocephalum* Chevrolat of Japan also feed on living plants. The genus *Blaps* Fab. (Nearctic), 189 species, has somber, robust, inert species with a wide distribution. The cellar or churchyard beetle, *B. mortisaga* Linn., a dull-black European species, 20-30 mm. long,

in olden times was feared as a messenger of death and pestilence. Adults of *B. gigas* (Linn.) were held alive in captivity for 3,349 days by Labitte (1916).

The ironclads, belonging to the genus *Phlaeodes* Lec., live under the bark of dead trees and stumps in California, are exceedingly slow and inert, and will remain motionless for hours. They have such a hard and thick exoskeleton that a steel needle is required to puncture the body in order to insert an insect pin. *P. diabolicus* Lec., and *P. pustulosus* Lec. are the commonest species.

The South African Toktokkies, *Psammodes reichei* Solier, are wingless black beetles which rap on the ground by raising and suddenly dropping the abdomen. Members of the genus *Helops* Fab. are active, medium-sized shining black or somber beetles that appear somewhat like carabids, and some are peculiar in that they climb grasses and are also arboreal.

XVI. Superfamily PTINOIDEA Leunis 1860

KEY TO FAMILIES

1. First tarsal segment longer than the second 2
First tarsal segment shorter than the second 3
2. Antennæ inserted on the front of the head close together at the base; thorax without lateral margin; head retractile, front and middle coxæ cylindrical, hind coxæ transverse. Small to medium-sized, elongated, robust, brown or blackish beetles. (Ptinid Beetles, Spider Beetles.) **PTINIDÆ** p. 577
Antennæ inserted on the sides of the head in front of the eyes and usually distant at the base; thorax usually with lateral margins. Small brown or black, elongated and depressed beetles. (Death Watch Beetles.) **ANOBIIDÆ** p. 576
3. First abdominal segment longer than the others; antennæ terminating in two saw-tooth segments; head prominent, free. Elongated slender black or brown beetles. (Powder Post Beetles.) **LYCTIDÆ**
First abdominal segment equal in length to the others; antennæ terminating in three or four saw-toothed segments, head deflexed and often hidden by prothorax. Usually robust or cylindrical brown or black beetles. (Branch and Twig Borers.) **BOSTRICHIDÆ** p. 575

Family LYCTIDÆ LeConte 1862 (Lyc'ti-dæ, from the Greek *Λύκτος*, mythical founder of Lyctus, city in Crete). Powder Post Beetles.

Small, narrow, elongated, flattened, obscure beetles which are smooth or pubescent and black, brown, reddish, or yellowish in color. Head prominent, somewhat deflexed but not covered by the prothorax. Antennæ short, 11-segmented with a two-segmented club. Eyes large. Thorax well developed. Legs slender, fore coxæ contiguous. Tarsi five-segmented, first very short and somewhat fused with the second; tibial spurs present. Elytra and wings normal. Abdomen with five visible sternites, the first elongated. Larvæ scarabæoid in form; legs short, three-segmented. These insects live in dead wood and are particularly destructive to dry hardwoods used for furniture, wooden ornaments, tool handles, and interior structural finishing.

There are only about 60 species, some of which have been widely distributed by commerce. The important genera are *Lycus* Fab. (cosmopolitan), *Minthea* Pasco (Holarctic), *Luctoxylon* Reitter (Japanese, North American), *Troxylon* LeConte (Nearctic and Neotropical). *Lycus* is the largest and most important genus, with 13 North American, one European, and three Australian species. The most important are *L. brunneus* (Stephens) and *L. linearis* (Goeze), both cosmopolitan; *L. cavicollis* Lec. and *L. planicollis* Lec., both American. All are injurious to hardwoods and manufactured articles of the same. The first is also a pest of bamboo.

Family BOSTRICHIDÆ (Leach 1815, 1817) (Bos-trich'i-dæ, from the Greek βόστρυκος, the name used by Aristotle for a winged insect; the male of the glowworm). Bostrichids, Branch and Limb Borers.

Small to large beetles usually elongated and cylindrical in form; smooth, rugose, sculptured or hairy, somber dark reddish-brown or blackish. Head hypog-

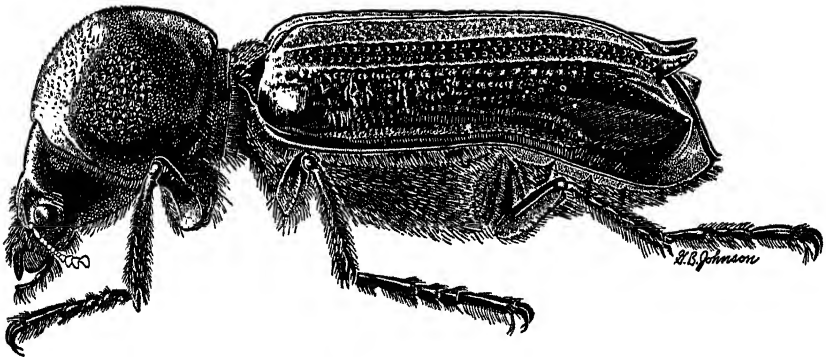


FIG. 195. The California palm borer, *Dinapate wrighti* Horn, one of the largest known bostrychid beetles.

nathous and invisible from above. Antennæ short, arising in front of the eyes, 11-segmented with three-segmented club. Pronotum hood-shaped, smooth, rugose, or tuberculate. Legs short; fore coxæ large, contiguous; tibial spurs present; tarsi five-segmented, first segment very small and almost invisible, second and fifth segments long. Elytra smooth or sculptured; posterior margins may be sloped and toothed. Abdomen with five sterna visible, the first much the longest. Larvæ scarabæoid, curved; head small; thorax greatly developed; blind; antennæ four-segmented, with first long; legs well developed. The larvæ of these beetles feed largely in dead wood and may be injurious to furniture and building materials. The adults of certain species feed upon living branches as well as boring into dead wood for oviposition. They are also attracted to wine barrels and casks and to the corks in bottles containing alcoholic liquids.

The family is a small one of some 400 species widely distributed. The important genera are: *Amphicerus* LeConte, *Bostrichus* Geoffroy, *Dinapate* Horn,

Dinoderus Stephens, *Polycæon* Laporte, *Psoa* Herbst, *Rhizophorthera* Stephens, *Scobicia* Lesne, and *Stephanopachys* Waterhouse. Among the smallest species are the Old World *Rhizophorthera dominica* Fab., 2.5–3.0 mm., and *Dinoderus minutus* Fab., 3–4 mm. in length, whereas the largest species known is the California palm borer, *Dinapate wrighti* Horn, which attains a length of from 30–55 mm. and a diameter of 14–20 mm. This large rugose, dark-brown, shining species lives in the native palms of California and Lower California. *Rhizophorthera dominica* Fab. (= *pusilla* Fab.) is a pest of stored wheat, which has become cosmopolitan in distribution.

One of the most interesting members of the family is the lead cable borer or short-circuit beetle, *Scobicia declivis* (Lec.), 5 mm. long and dark-brown and black. This beetle breeds in dead wood, but the adults frequently bore holes into the aerial lead telephone cables permitting the entrance of water and thus short-circuiting the wires. This damage has been considerable some years in parts of California. This beetle also damages filled and empty wine casks and containers, as well as corks, by drilling holes through the wood and causing leaks. *Xylion cylindricum* MacLeay of Australia similarly damages wine casks and barrels.

Family ANOBIIDÆ Shuckard 1840 (An'o-bi'i-dæ, from the Greek ἀναβίωω, to return to life). German, Pochkäfer. French, Anobiides. Death Watches.

Small, somber, short, cylindrical beetles scarcely more than 6 mm. in length. Head hypognathous and hidden under the prothorax. Antennæ inserted on anterior margins of eyes; serrate, pectinate, or clavate, with the three apical segments enlarged and free. Prosternum short. Legs short; fore and middle coxæ small, fore pair conical and open behind, hind pair transverse and grooved to receive femora. Tarsi five-segmented. Abdomen with five equal visible sternites. Larvæ scarabæoid, very small, and living in dead and usually well-seasoned hardwoods.

The adults of certain genera have long been known as death watches from the fact that their mating call, sounded during the months of April, May, and June, consists in a series of sharp taps of the head against the walls of their burrows. In northern Europe, where oak and other hardwoods were extensively used in constructing buildings, these beetles often infested the timbers in very great numbers and during the quiet of the night their regular, clock-like tapplings against the dry resonant wood was long thought to portend death. The destruction which the tapping foretold was not to humans but rather to the strong oak beams which were slowly and surely being devoured. So great has been the damage from these insects that the massive roofing timbers in many of the magnificent old cathedrals and government buildings in Great Britain have been removed and replaced by steel or chemically treated wood. In nature they breed in the dead parts of oaks, willow, hawthorn, and other hardwood trees.

The members of the family have varied habits, but in general they feed chiefly upon dead and cured or dry animal and vegetable matter. Because of

these habits they have long been associated with man ¹ and have been widely distributed in commerce.

There are over 100 genera and 1,150 described species. Some of the important genera are *Anobium* Fab., *Calorama* Guérin, *Dryophilus* Latr., *Ernobius* Thomson, *Hedobia* Latr., *Lasioderma* Stephens, and *Stegobium* Motschulsky.

The furniture beetle, *Anobium striatum* Olivier, 3–5 mm., and the death watch beetle, *Xestobium rufovillosum* De Geer, 6–9 mm., are two of the commonest and the most destructive species infesting cured hardwoods in furniture and in buildings in many parts of Europe. The destruction of the great roof timbers in York Cathedral, Westminster Hall, and other old and famous buildings in Great Britain is largely due to the work of the latter. The former also occurs in North America. The cigarette beetle, *Lasioderma serricorne* (Fab.), brown and 2.0–2.5 mm. long, is an Old World species, now cosmopolitan in distribution, which feeds upon many kinds of dried plant and animal materials such as tobacco, spices, seeds, cereal products, copra, dried fruits, and cured fish and meats. The drugstore beetle, *Stegobium paniceum* (Linn.) (*Sitodrepa*), 2–3 mm. and brownish, gets its name from feeding on herbs used for drugs. It feeds upon many kinds of plant and animal products and is a serious pest in most parts of the world.

Family PTINIDÆ (Leach 1815, 1819) (Ptin'i-dæ, from the Greek *πτῆνός*, winged, feathered; referring to the pectinate or flagellate antennæ).
Ptinid Beetles, Spider Beetles.

A family of small, somber, oval or cylindrical beetles. Head small but visible from above. Head and prothorax much narrower than the rest of the body. Antennæ long, filiform or moniliform; inserted on frons; two-, six-, or 11-segmented, capitate. Prosternum short. Trochanters attached at bases of femora. Coxæ of fore and middle legs contiguous; transverse in hind legs. Abdomen with five visible sternites. Larvæ scarabæoid, with short, five-segmented legs. A number of species construct cocoons for pupation. All forms are scavengers and feed upon dead and dried animal and vegetable matter. Some forms are inquilines in ants' nests.

The widely distributed family consists of about 550 species. The most important genera are *Gibbium* Scopoli, *Mezium* Curtis, *Niptus* Boieldieu, *Ptinus* Linn., and *Sphæricus* Wollaston.

The storehouse beetle, *Gibbium psylloides* ² (Czempinski) (= *scotias* Fab.), 2.5–3.0 mm., brownish, one of the most important and destructive species, is cosmopolitan and injurious to all kinds of vegetable and animal foodstuffs and other products. The following species have similar habits: *Mezium affine* Boield., 2.3–3.0 mm., reddish-brown, of Europe; *M. americanum* Laporte,

¹ Specimens of the two species *Lasioderma serricorne* (Fab.) and *Stegobium paniceum* (Linn.) were found in the tomb of the Egyptian King Tutankhamen and are said to be 3,500 years old (Alfieri, 1931).

² This beetle was found dead in the tomb of the great Egyptian King Tutankhamen along with other species and had apparently been imprisoned there for 3,500 years. See footnote 1.

2.3–3.0 mm., dull yellow with black elytra, of North America; the spider beetles, *Niptus hololeucus* Faldermann, 4.0–4.5 mm., brown; *Ptinus fur* Linn., 2.0–4.5 mm. brownish and white; *P. brunneus* Duftschmid, 2–3 mm., blackish-brown; and *Sphaericus gibboides* Boield., 1.5–2.0 mm., brown. All of these are practically cosmopolitan and are often abundant in warehouses, granaries, mills, and wherever animal and vegetable products are manufactured and stored. Most of these insects may also attack the leather backs and glue of books.

XVII. Superfamily SCARABÆOIDEA Bedel 1911

KEY TO IMPORTANT FAMILIES

1. Lamellate segments of antennal club comb-like or pectinate and not capable of being closely coadapted 2
 Lamellate segments of antennal club thin and leaf-like and capable of being closely coadapted; antennæ not elbowed; abdomen with five or six visible rigid or free sternites; elytra rough, smooth, hairy, or scaly. Small to large robust dull or brightly colored, often metallic beetles. (June Beetles, Lamellicorn Beetles, Cockchafers, etc.) 3
2. Antennæ not elbowed but usually curved so as to appear elbowed; mentum deeply emarginate, the ligula large, corneous, and filling the emargination; front of head with a short bent horn pointing forwards; body pedunculate; elytra striate and glabrous. Large oblong shining brown or black beetles. (Horned Beetles.) **PASSALIDÆ**
 Antennæ usually elbowed, rarely straight; mentum entire and usually completely covering the maxillæ; mandibles prominent and strongly developed in the males. Large smooth, rough, striate or punctate black and brown beetles. (Stag Beetles.) **LUCANIDÆ** p. 587
3. Abdomen with six tergites; side pieces of metasternum attaining coxæ 4
 Abdomen with five tergites; side pieces of metasternum not attaining coxæ; body roughly sculptured, elytra frequently tuberculate. (Skin Beetles.) **TROGIDÆ** p. 582
4. Mentum and ligula separated; abdominal spiracles all on membrane between tergites and sternites 5
 Mentum and ligula fused; abdominal spiracles at least in part upon sternites 10
5. Hind tibiz with a single terminal spur; scutellum small or invisible; middle legs widely separated. (Tumble-bugs, Scarabs, etc.)
 **SCARABÆIDÆ** p. 579
 Hind tibiz with two terminal spurs; scutellum distinct; middle legs approximate 6
6. Antennæ 11-segmented 7
 Antennæ not more than 10-segmented 8
7. Antennal club three-lamellate. **GEOTRUPIDÆ**
 Antennal club four- to seven-lamellate **PLEOCOMIDÆ** p. 582
8. Antennæ nine-segmented 9
 Antennæ 10-segmented; body very hairy; metepimera large; antennal club glabrous **GLAPHYRIDÆ**

- | | | |
|---|--------------|--------|
| 9. Mandibles concealed beneath clypeus | APHODIIDÆ | p. 582 |
| Mandibles exposed, not covered by clypeus | ÆGIALIIDÆ | |
| 10. Abdominal spiracles in two only slightly posteriorly divergent rows,
each row forming a single straight line | MELOLONTHIDÆ | p. 583 |
| Abdominal spiracles in two strongly posteriorly divergent rows, each
row forming two lines | | 11 |
| 11. Claws of posterior tarsi subequal in length | | 12 |
| Claws of posterior tarsi unequal in length, movable; pygidium exposed | RUTELIDÆ | p. 583 |
| 12. Mandibles expanded, visible from above | DYNASTIDÆ | p. 585 |
| Mandibles not expanded, not visible from above | CETONIIDÆ | p. 586 |

Family SCARABÆIDÆ Latreille 1802 (Scar'a-bæ'i-dæ, from the Greek *κάραβος*, a horned beetle, and the Latin *scarabæus*, a dung beetle). German, Maikäfer, Blatthornkäfer, Mistkäfer, Rosskäfer, Dungkäfer. French, Les scarabées. Scarabs, June Beetles, May Beetles, Dung Beetles, Cockchafers, etc.

This family, as defined by the older entomologists, constituted a very large group that was divided into six or more subfamilies. Modern workers are not agreed as to its present status, but there is a strong tendency to consider the family as conceived by such entomologists as Westwood, Sharp, LeConte, and Horn as a superfamily and to elevate the subfamilies to families along with many new additions, so that as many as 19 families have resulted. Under this new system it is now necessary to think of many comprehensive units that should be treated separately. However, such an extensive discussion is impossible in this work so it has been thought advisable to tabulate the important and distinctive characters of the group as a whole and then to treat the other more important families separately and briefly.

The adults are very small to giant robust diurnal and nocturnal, terrestrial beetles, mostly elongate-oval, somewhat cylindrical, flattened, or globular in form; smooth, shining, metallic, enameled, scaly, and often conspicuously hairy, especially ventrally; colors are of all imaginable hues and combinations from dull and somber to the most brilliant and jewel-like

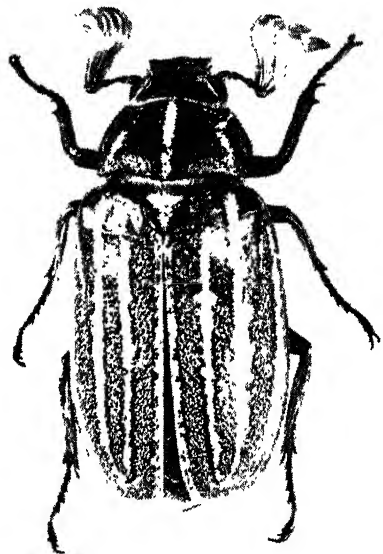


FIG. 196. The coast lined June beetle, *Polyphylla crinita* LeConte. Male with lamellæ of the antennæ extended. (By Van Dyke from *Insects of Western North America*.)

metallic and enameled surfaces. The tropical species rival all other objects in nature for beauty of color and design. It is inconceivable how insects can so perfectly match the colors of precious metals and jewels. In this respect the beetles are unsurpassed. Integument firm, soft, and pliable or hard and heavily sclerotized. Head prognathous or partially hypognathous; small or large, free, or partly surrounded by prothorax; often with marginal plates and horny structures. Eyes large. Antennæ variable but usually elbowed and capitate, the enlarged apical segments loosely connected and serrated or fitted together into compact elongated or globular knob-like segment as the leaves of a book or lamellæ, in which latter case they are referred to as lamellate. Those of the males are often greatly enlarged while in the females of the same species they are very small. Mouth parts are poorly or strongly developed; the mandibles horizontal or vertical and in certain groups very prominent in the males. Prothorax large and prominent, often as large or even larger than the rest of the body; simple or with horny structures. Legs strong, the fore pair usually fossorial. Tibiæ dilated and usually with spurs, those of the forelegs strongly toothed. Tarsi five-segmented, long, or sometimes reduced or absent on the forelegs. Claws normally paired, large and strong. Wings well developed, reduced, or rarely absent. Elytra normally covering the abdomen or truncate and exposing the pygidium. Abdomen robust, with six visible sternites.

The larvæ are typically scarabæoid, with fleshy, curved, wrinkled, and more or less hairy bodies; large flat, sclerotized head; strong mandibles; well-developed antennæ; long legs; and enlarged posterior abdominal region.

The pupæ are free and usually occur in the normal habitat of the larvæ, enclosed in a cell composed of surrounding materials.

The whole group, or superfamily SCARABÆOIDEA, consists of no less than 30,000 species which occur throughout all plant-inhabited parts of the world. In the family SCARABÆIDÆ there are about 14,500 species.

The members of the typical family SCARABÆIDÆ (or COPRIDÆ), as indicated in the above heading, comprise some of the most remarkable animals known. They live largely upon dung of mammals which is usually rolled by the adults into regular or irregular balls that are then buried in subterranean chambers of variable sizes several inches below the surface of the soil. These dung balls not only serve as food for the adults but certain differently shaped ones are placed in separate brood chambers. In each of these latter balls the female deposits a single egg and the larva feeds inside the mass which furnishes sufficient food to ensure its complete development. The adults may be nocturnal, often fly on warm rainy nights, and are attracted to lights. However, the dung balls are rolled and buried during the day.

These are the beetles which the great French entomological naturalist Fabre has so accurately and interestingly described in his accounts on insects. Among them are included the famous Egyptian scarabs which for hundreds of years

played an important part in the religion and life of the great civilization on the Nile. Artificial scarabs were made as early as 3000 B.C. The earliest of these were the finest: small and delicately and beautifully colored. Those of the XI Dynasty were glazed blue and were very fine. The art of glazing deteriorated after the XVIII Dynasty, and scarabs were very poor under Rameses II and his successors. They were made of clay, stone, jewels, and precious metals. Glazed colors included green, brown, white, and blue.

These artificial scarabs were mythological, historical, physiographical, funeral, talismanic, signets, and designs. They were largely copied from four genera: *Catharsius* Hope, 82 spp. (Palearctic, Ethiopian, and Indo-Malaysian), *Copris* Geoffroy, 140 spp. (Ethiopian, Holarctic, Indo-Malaysian, and Neotropical), *Gymnopleurus* Illiger, 99 spp. (Ethiopian and Palearctic), and *Scarabæus* Linn., 79 spp. (Ethiopian, Palearctic, and Indian), all belonging to this family and to *Hypselogenia* Burmeister, 5 spp., of the family CETONIDÆ. One of the most important of these is the sacred scarab, *Scarabæus sacer* Linn., a dull-black species 25 mm. long, which is very broad and characterized by having a semi-circular row of five teeth on the front of the head and much larger projections on the fore tibiae. At rest these fore tibiae are brought in front of the head, giving a cogwheel-like appearance. Labitte (1916) kept adults in captivity for 633 days.

According to Maxwell-Lefroy (1909) the majority of the conspicuous Indian scarabs, or over 100 species, belong to this family. Imms (1930) refers to egg balls of certain species of *Heliocopris* Hope and *Cartharsius* as being covered with clay and so hard and large as to have been mistaken for buried ancient stone cannon balls. Other important genera are *Onihophagus* Latr., cosmopolitan, and the largest genus with 1393 spp.; and *Phanæus* MacLeay, 81 spp., both Holarctic.

Some forms are recorded as being myrmecophilous.

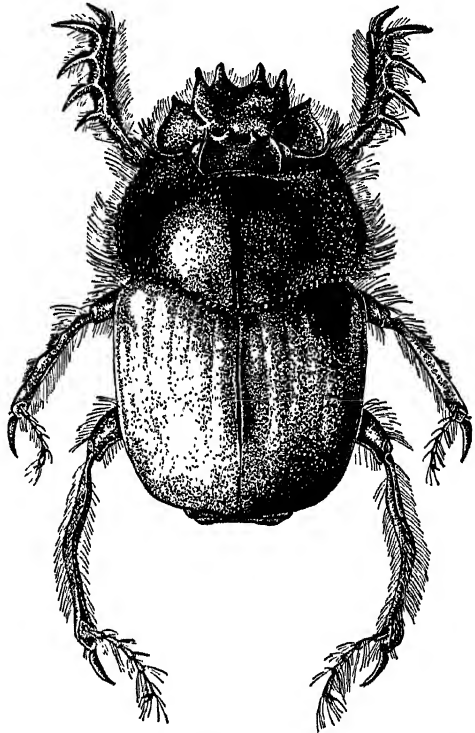


FIG. 197. The Egyptian sacred scarab, *Scarabæus sacer* Linn., long an object of worship and respect during ancient times in Egypt.

Family APHODIIDÆ (Leach 1815) (A-pho-di'i-dæ, from the Greek ἄφωδος, dung; referring to breeding in dung). Small Dung Beetles.

Small, smooth, striated, and often hairy, slender or cylindrical species black or brown in color; head usually hypognathous, with or without tubercles and rarely horned; antennæ nine-segmented; mandibles visible below clypeus; thorax with or without transverse callosities, epimera of metathorax covered; apical spur of hind tibiæ acute, dilated, or truncate. These small beetles breed abundantly in dung. They often swarm from cow pastures in incredible numbers and fill the air on warm or rainy afternoons, evenings, and nights, many being attracted to lights. This is a fairly large group of scarabæoid beetles and is very widely distributed, being especially common in prairie and grassland areas occupied by ruminant mammals. The largest and most important genus is *Aphodius* Illiger, 725 species, of which 103 species are North American. Leng also records nine fossil species from Miocene and one from Pleistocene.

Family PLECOMIDÆ Arrow 1913 (Ple'o-com'i-dæ, from the Greek πλέος, full, + κόμη, hair, pile; referring to the very hairy species). Pleocomids.

The members of this very small family are limited to 26 species in the genus *Pleocoma* LeConte, all of which occur in the Pacific coast states (and Utah) including Mexico and Lower California northwards into Alaska. The species are characterized by the bifurcated front of the head; small upright horn between the eyes; 11-segmented antennæ with three- to seven-segmented club; free abdominal sternites, VI retractile within V; and spiracles on lateral membrane.

Pleocoma inhabits hilly and mountainous areas and lives in the soil, the large larvæ feeding upon the roots of shrubs and trees. Upon reaching maturity the adults excavate a large cylindrical hole to the surface and emerge with the first rains in the fall of the year. The males fly freely in the rain with a loud humming noise, but the much larger, heavy females have lost the power of flight. As soon as the males find the opened female burrows, they enter and mating results. The females return into the soil to lay their eggs and to die. *Pleocoma fimbriata* Lec. was the first species described, but many more specimens of *P. behrensi* Lec. have been collected (see E. G. Linsley, *Pan-Pacific Ent.* 14: 49-58, 97-104, 1938).

Family TROGIDÆ MacLeay 1819 (Trog'i-dæ, from the Greek τρώξ, τρωγός, a gnawer.)

Oblong, rugose, dusty-looking, somewhat hairy, brownish beetles of medium size which are characterized by nine- or 10-segmented antennæ with large club and the first saucer-shaped segment enclosing several following segments; and large vertical mandibles. They are carrion and dung feeders and often burrow into the ground about dead carcasses.

It is a small family composed of three genera: *Cryptogenius* Westwood (South American), 2 spp., *Glaresis* Erichson (Holarctic), 8 spp., and *Trox* Fab. (cosmopolitan), 147 spp., *Trox hispidus* Pontoppidan, 9-11 mm. long, is a common

species in middle Europe, while there are three species common to England. In North America 21 species are listed by Leng.

Family MELOLONTHIDÆ Leach 1817, MacLeay 1819 (Mel'o-lon'thi-dæ, from the Greek *μηλολόνηθς*, the cockchafer; the common name applied to these beetles). Cockchafers, May Beetles, June Beetles.

Small to large, slender or robust, somewhat cylindrical species which are smooth, striated, or rugose and partly hairy; variously colored, black, brown, mahogany, green, blue, and all shades of metallic colors — tropical and sub-tropical forms may be beautifully marked and brilliant; head of males sometimes with horny processes; antennal club often elongated in males; mouth parts strong, labrum and mandibles hidden beneath clypeus, mentum large and quadrate; prothorax narrow or as wide as abdomen; legs often very long and slender or strong, hind femora slender or thick, tibiæ with one, two, or no spurs, claws toothed or simple, usually a pair, rarely one only on middle and hind legs; elytra rarely covering the pygidium of the female; abdomen with five visible sternites; spiracles in row on upper portions of the ventral segments — the last one visible behind the elytra. Larvæ typical scarabæoid form. They are largely root feeders and therefore subterranean.

This is one of the largest of the scarabæoid families and contains over 5,000 species, among which are some of the most injurious species of insects known. Especially destructive to forest trees are the genera *Dichelonyx* Kirby (North and South American), 28 spp., *Melolontha* Fab. (Holarctic, Indo-Malaysian), 41 spp., *Polyphylla* Harris (Holarctic), 35 spp., and *Serica* MacLeay (Nearctic, Neotropical, Ethiopian, Indo-Malaysian), 92 spp. Among all of these the forest maybeetle, *Melolontha melolontha* (Linn.) (= *vulgaris* Fab.), is by far the most important and destructive. It occurs in the forests of Europe and western Asia and, with the possible exception of the honeybee, has been the object of more written reports than any other European insect. The field maybeetle, *M. hippocastani* Fab., a Palearctic species, is also a pest of much importance. The species of *Serica* are small dull-colored, black, reddish, and brown species which are also defoliators of fruit trees. *Hoplia* Illiger (Holarctic, Ethiopian, and Indo-Malaysian), 220 spp., are most interesting, small, often metallic beetles that have but a single hind claw. The adults are flower, fruit, and leaf feeders. *Macrodactylus* Latr. (Nearctic and Neotropical), 60 spp., is famous because of the notorious rose chafer, *M. subspinosus* Fab., the larvæ of which attack the roots and the adults the flowers and foliage of roses in North America. The genus *Diplotaxis* Kirby, 129 spp., is North American; *Heteronyx* Guérin, 319 spp., and *Liparetrus* Guérin, 120 spp., are Australian; and *Apogonia* Kirby, 172 spp., is Palearctic and Indo-Malaysian.

Family RUTELIDÆ MacLeay 1819 (Ru-tel'i-dæ, from the Latin *rutilus*, red, golden red; referring to the brilliant colors of some of these beetles). Rutelian Beetles.

Medium-sized beetles closely related to the melolonthids, but which are characterized by having the labrum chitinated; hind tibiæ with two apical spurs;

unequal claws especially on the hind legs, each claw free, the shorter one simple; elytra with or without membranous border; three spiracles on the membrane between the dorsal and ventral pleurites and three visible ones on the ventral plates. These beetles are mostly brilliant and metallic blue, green, brown, yellow, or golden, and reddish, and are among the finest of beautiful insects. They form a group of very destructive pests especially in the forests and plains areas.

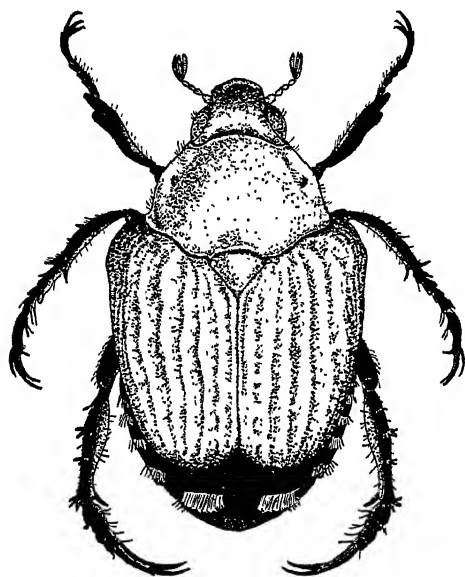


FIG. 198. The Japanese beetle, *Popillia japonica* Newman, a beautiful green and brown oriental species accidentally introduced into eastern United States prior to 1916 and which has proven to be a serious pest there.

Many species have been widely distributed on plant materials and have wrought havoc among forest, fruit, and ornamental trees and shrubs, especially deciduous and broad-leaved varieties. The family reaches its greatest development in the tropics but has many representatives in the temperate regions.

The most important economic genera are: *Anomala* Samouelle, 799 spp., the largest and the most widely distributed cosmopolitan genus. Many species are rated as serious pests in tropical and eastern Asia. The Asiatic beetle, *A. orientalis* Waterhouse, a widely distributed Asiatic and Malaysian species, was introduced into the United States and first discovered in Connecticut in 1920. Its distribution is gradually increasing in the northeastern

parts, and it is regarded as a pest of some consequence. *Adoretus* Laporte, 253 spp., is widely distributed in the Old World, but is absent in the New World except where introduced.

The Chinese rose beetle, *A. sinicus* Burmeister, introduced into Hawaii before 1896, has become a well-established pest there. *Cotalpa* Burm., 18 spp., *Pelidnota* MacLeay, 87 spp., and *Plusiotis* Burm., 45 spp., are North and South American. *Popillia* Serville, 216 spp., is another Old World genus which is represented in the eastern United States by the famous introduced Japanese beetle, *P. japonica* Newman, which first appeared in New Jersey in 1916. It is a beautiful metallic dark-green species with brown elytra and from 15–18 mm. long. Both the subterranean larvæ and adults seriously injure living plants including all kinds from lawns to forest trees.

Family DYNASTIDÆ MacLeay 1819 (Dy-nas'ti-dæ, from the Greek *δυνάστης*, lord, master, ruler; referring to the regal appearance of these large beetles).

Medium-sized to among the largest known insects, elongated and somewhat cylindrical, smooth and shining or dull, rugose or sculptured; metallic or bril-

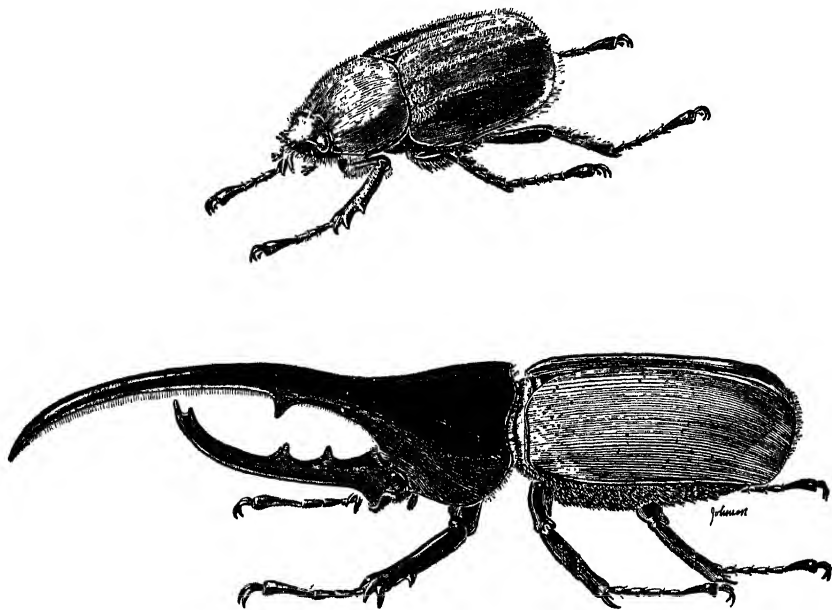


FIG. 199. The Hercules beetle, *Dynastes hercules* (Linn.), a huge and highly-prized beetle inhabiting tropical North and South America. It is one of the largest insects. Slightly enlarged.

liant in coloration; head and pronotum armed or unarmed with crests and tubercles in either or both sexes; labrum membranous, fused to head; mandibles visible from above, bent foliate, and sometimes notched; prosternum produced forward as a lobe; fore coxæ transverse; hind tibiæ two-spurred; tarsi short or long.

This family is best developed in North and South America, but is also well represented in Africa and Australia and poorly represented in Europe and Asia. In it belongs the remarkable Hercules beetle, *Dynastes hercules* (Linn.), of tropical North and South America, in which the female is dull brown, punctured, and with a small obscure tubercle on the head and 65 mm. long, whereas the male is shining black with spotted dull-green elytra, has a long toothed upcurved horn on the head 40 mm. long, and the pronotum produced into a long downcurved horn, with two large denticles and lined with fine amber-colored hairs, which, with the prothorax, is 95 mm. long. The rest of the body is 45 mm. long. It is highly prized by collectors. *D. tityus* (Linn.) also of tropical America and ranging into the United States is a beautiful enameled green-

ish-gray species with dark spots measuring up to 45 or 55 mm. for the male and 45 mm. for the female. The male has one horn on the head and one large median and two small ones on the pronotum. The palm rhinoceros beetle, *Oryctes rhinoceros* (Linn.), of tropical Asia, 30-45 mm. long, is a finely punctured dark reddish-brown species, the females being hornless and the male with a stout upright horn on the head. There is also an interesting species, *O. boas* (Fab.), in Africa. The atlas beetle, *Chalcosoma atlas* (Linn.), of tropical Asia is a grotesque, shining, dark-mahogany species 100 mm. long, including the two long curved pronotal horns. There is also a short median horn on the pronotum and a long stout head horn.

Among the many other genera, *Cyclocephala* Latr. (Holarctic) and *Ligyris* Burmeister (Nearctic) should be mentioned. In the latter is the very common and abundant muck or carrot beetle, *L. gibbosus* (DeGeer), 16 mm. long and shining reddish-brown, which occurs throughout much of North America and is attracted to lights.

Family CETONIIDÆ MacLeay 1819 (Ce'to-ni'i-dæ, from the Greek κήτειος, monstrous; referring to the large size of these beetles). Flower Beetles, Sap Chafers.

These are medium-sized to large, mostly brightly colored tropical and sub-tropical species characterized by the wide, dorsally flattened bodies; large scutellum; spiracles in dorsal parts of ventral segments, absent on pygidium; mouth parts poorly developed; mandibles weak; labrum membranous and hidden; maxillæ hairy; fore coxæ vertical. The adults are mostly diurnal and commonly feed on flowers, fruit, and other parts of living plants. The larvæ are secluded and feed on decaying vegetable matter and the roots of plants. The members of the tribe CREMASTOCHEILINI are myrmecophilous and termitophilous.

The family numbers about 2,500 species. The most remarkable members are the goliath beetles belonging to the African genus *Goliathus* Lamarck, containing seven species. Of these, *G. atlas* Nickerel and *G. goliathus* Drury are the bulkiest insects known. The large males measure up to 125 mm. long, 50 mm. wide across the humeri, and 30 mm. thick through the thorax. The color is rich velvety reddish-brown with white longitudinal lines on the pronotum and other white markings on the head and the elytra. They roll dung balls as large as small apples. For a number of years after their discovery they were so eagerly sought by collectors that as much as \$150 to \$250 apiece were paid for them.

Probably the finest and best known European species is the goldsmith beetle, *Cetonia aurata* (Linn.), which is a brilliant golden species 14-20 mm. long, occurring as far east as eastern Siberia. The genera *Cotinis* Burmeister, 37 spp., *Euphoria* Burm., 70 spp., and *Gymnetis* MacLeay, 11 spp., are North and South American, and the interesting myrmecophilous genus *Cremastocheilus* Knoch, 28 spp., is North American. The latter are odd flat-backed rectangular black species found flying or crawling on the roads on warm spring days. In North America the most familiar species are the bumble flower beetle, *Euphoria inda* (Linn.), 13-16 mm. long, yellowish-brown, mottled with black and hairy;

the fig-eater, *Cotinis nitida* (Linn.), 20–23 mm. long, metallic green and brownish; and the green fruit beetle, *C. texana* Casey, 20–34 mm. long and opaque and brilliant green.

Family LUCANIDÆ (Leach 1815, 1817) (Lu-can'i-dæ, from the Latin *lucanus*, sunrise; a scarab reported by Pliny). German, Kammhornkäfer, Hirschkäfer, Schröter. Stag Beetles, Lucanids.

Large elongate-oval or robust beetles which are usually black or brown and with smooth, shining, hard integument. The mandibles of the male may be enormously enlarged and even antler-like. The head is large and strong. Antennæ geniculate, 11-segmented, with the three terminal segments enlarged and flabellate. Eyes large. Labrum indistinct; ligula and maxillæ hidden beneath the mentum. In many respects these beetles and their larvæ greatly resemble the scarabæids.

The larvæ of known species live largely in wet or damp, dead, and decaying wood, and the species are more or less restricted to forested areas. The adults most frequently fly at night. The family is a small one consisting of only about 900 species. It reaches its greatest development in the tropics and tapers off in the temperate regions.

Although this family is represented in all parts of the world, no single genus is truly cosmopolitan. Important Holarctic genera are *Pseudolucanus* Hope, 10 spp., and *Sinodendron* Hellweg, 4 spp. (family SINODENDRIDÆ of authors). *Dorcus* MacLeay, 26 spp., and *Lucanus* Scopoli, 26 spp. (Holarctic and Indo-Malaysian); *Platycerus* Geoffroy, 18 spp. (Holarctic and Neotropical). *Aegus* MacL., 67 spp., *Cyclommatus* Parry, 32 spp., *Eurytrachelus* Thomson, 39 spp., *Nigridius* MacL., 38 spp., and *Odontolabis* Hope, 50 spp., are Chinese and Indo-Malaysian; *Chaisognathus* Stephens, 7 spp., and *Sclerognathus* Hope, 23 spp., are Neotropical; and *Lissotes* Westwood, 29 spp., is Australian.

The largest European species is the stag beetle, *Lucanus cervus* (Linn.), brownish-black and 27–75 mm. long. The commonest species in eastern North America is *L. capreolus* (Linn.) (= *dama* Fab.), 22–35 mm. long and brown in color. The giant stag beetle of the southern states is *L. elephas* Fab., 35–50 mm. long.

Among the remarkable species should be included the following: *Chaisognathus granti* Stephens of Chile, brilliant dark bronze-green with red reflections. The curiously forked mandibles of the male are 50 mm. long, fully as long as the rest of the body. The giraffe stag beetle, *Cladognathus giraffa* (Fab.), of south India and Java, reddish-brown and black, has very formidable-looking toothed mandibles which are quite as long as the body. Perhaps the largest species is *Odontolabis alces* Fab. of the East Indies, which may attain a length of 100 mm. and a great width. *Cyclommatus tarandus* Thunberg of Borneo and *Eurytrachelus titanus* Boisduval of the East Indies are also remarkable species. The largest Australian member of the family is *Lissotes acmenus* Lewis, 40 mm. long and 20 mm. wide, shining black, and with the head, mandibles, and prothorax very greatly enlarged and the rest of the body relatively small. *Di-*

phyllostoma Fall, containing some of the smallest species, 5–9 mm., have the females wingless and are thought to feed on grass roots; three species are known to California. They fly in the daytime, while most other lucanids are nocturnal (Linsley, E. G., *Pan. Pac. Ent.*, 8:109, 1932).

XVIII. Superfamily CERAMBYCOIDEA Leng 1920

KEY TO FAMILIES

1. Mentum pedunculate; front prolonged into a broad quadrate beak; antennæ short, serrate or pectinate, inserted in front of the eyes; prosternum very short; hind femora usually thickened; body short, more or less oval, tip of the abdomen exposed. Small robust seed-infesting beetles. (Pea and Bean Weevils.) **LARIIDÆ** p. 595
Mentum not pedunculate 2
2. Body short and somewhat oval; antennæ short or not greatly lengthened and not inserted on frontal prominences; front small, oblique or inflexed; thorax frequently margined, tibial spurs usually absent. Minute to small oval dull or brightly colored, smooth, hairy or scaly plant-eating beetles. (Leaf Beetles.) **CHRYSOMELIDÆ** p. 592
Body elongate; antennæ usually long and often greatly lengthened and frequently inserted on frontal prominences; front often large, vertical, and quadrate; thorax rarely margined; tibial spurs distinct. Medium to large slender or cylindrical dull or brightly colored, smooth, punctate, hairy or scaly wood-boring beetles. The adults of some frequent flowers. (Long-horned Beetles.) **CERAMBYCIDÆ**

Family CERAMBYCIDÆ (Leach 1815, 1817) (Cer'am-byc'i-dæ, from the Greek *κεράμβυξ*, a horned beetle; from the long antennæ). German, Bockkäfer. Long-horned Beetles, Cerambycids, Longicorns.

Small to large, elongate, somewhat flattened or cylindrical beetles characterized by the very long antennæ in many species. The integument is soft, leathery, parchment-like, or hard; smooth, shining, punctate, callosed, rugose, striate, sculptured, or spined; clothed partially or entirely with hairs and scales; colors somber and cryptic or ranging through all shades of beautiful enameled¹ and metallic hues rivaling all other insects in variety and beauty of coloration. Head prognathous or subhypognathous; large, free, may be excavated between the eyes. Eyes large, irregular, partly encircling the bases of the antennæ or divided. Antennæ simple or serrate, some ornamented with tufts of hair; much shorter than the body to variable lengths up to more than twice the length of the body, and filiform. Mouth parts large and powerful. Mandibles large, strong, and toothed, in some forms excessively enlarged and almost antler-like. Palpi usually well developed, slender, or dilated. Prothorax narrow or as wide as the mesothorax; unarmed, spined, or tuberculate. Wings absent in certain

¹ Enameled colors are those that are without metallic luster or iridescence and may be due to pigmentation.

The treatment of this family was approved by E. G. Linsley.

genera (*Ipochus* Lec., *Dorcadion* Dalman, *Moneilema* Say, *Plectrura* Mannerheim), but are normally well developed, enabling powerful flight. Elytra usually cover the body but leave the posterior tip of abdomen exposed in a few cases. Legs long, slender, smooth, spined or variously ornamented or hairy. Coxæ variable in size, shape, and position. Tibial spurs minute to large. Tarsi long, five-segmented, some dilated, hairy or pubescent, segment III bilobed, segment IV greatly reduced, usually fused with V. Claws strong. Abdomen large, the posterior segments of the female sometimes greatly elongated for egg laying; with five or six visible sternites. Larvæ cerambycoid type (fleshy, long, straight, and subcylindrical), apodous or with vestigial legs, smooth or wrinkled and often pubescent, distinctly segmented. Head small and with powerful mandibles. Prothorax large. Terminal segment often longest. Pleural or astitial disks may be present on the pleurites. Because of the large thorax these larvæ are frequently referred to as round-headed borers. They have long been used as an article of food by primitive peoples.¹

The adults are diurnal or nocturnal and frequent dead and living small woody plants, shrubs, and trees as well as flowers. They are mostly rather slow and sluggish excepting during the heat of the day when the flower visitors are as active as bees and wasps that some of them mimic to a remarkable degree. In such a large group many diverse forms and peculiarities in habits occur. Sexual dimorphism is apparent in many species. The females are often the larger, but the males nearly always have much longer antennæ.

Odorous species are represented by the European musk beetle, *Aromia moschata* (Linn.), metallic green, coppery, and blue, 20–30 mm. long, which has an "attar of roses" scent. It breeds in dead willows. Species in a great many genera stridulate.

The eggs are usually laid on or inserted into the tissues of the host plant. This latter feat is accomplished by cutting slits in the wood by means of the sharp mandibles and then inserting the egg with the pointed ovipositor. Egg laying is



FIG. 200. The black pine sawyer, *Monochamus scutellatus* (Say), a common long-horned beetle inhabiting the coniferous forests of North America. (From *Insects of Western North America*.)

¹ The larvæ of the larger species have generally been an article of diet. In America those of *Prionus* were considered a great delicacy while in Australia Tillyard refers to the "Hu-hu" or larvæ of *Prionoplus reticularis* White and of Bardee, *Bardistus cibarius* Newman, as being used for food not only by the natives but also by the whites.

sometimes accompanied by girdling the living twigs below as well as above the eggs to kill that part of the host. The larvæ infest all parts of the plant, and certain species attack the roots, trunks, limbs, and cones and may confine their feeding to the epidermal layers or to the heartwood. All known members of the family are phytophagous and, while the larvæ feed as borers on both living and dead plant tissues, the adults either do not feed at all or partake of living foliage

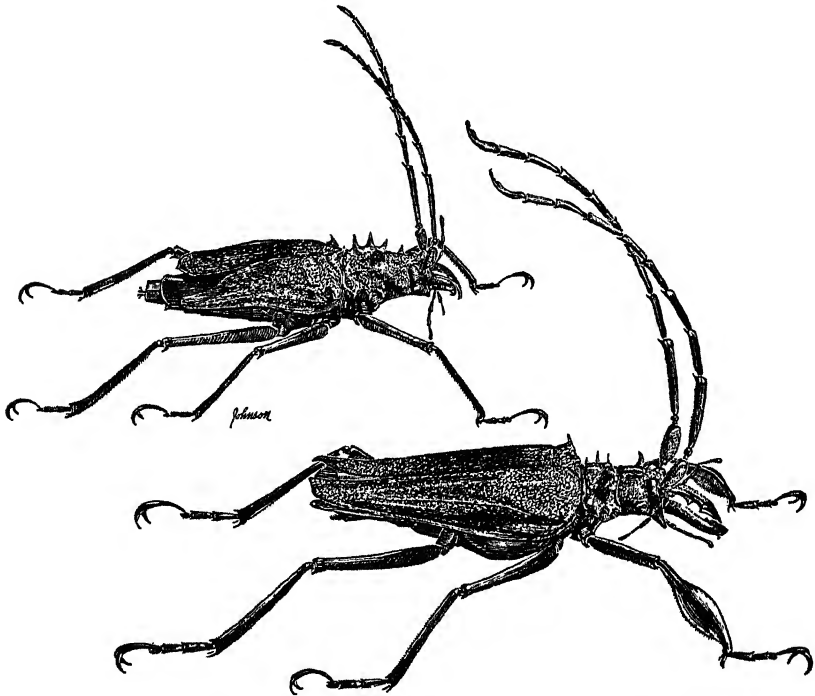


FIG. 201. *Psalidognathus superbus* Fries, a magnificent brilliant metallic green long-horned beetle living in the forests of tropical South America. Male and female somewhat reduced in size.

and bark, pollen, or fungi. The Australian *Mesolita myrmecophila* Lea and the American genus *Eplophorus* Chevrolat are associated with ants.

The life history consumes rarely less than a year, and in many species from 2 to 4 years are required to complete a cycle. The members as a group may be classed as forest insects and their distribution, which coincides with that of the available hosts, includes most of the world. The family is about sixth in size in the order and contains approximately 20,000 species. It reaches its greatest development in the tropics where the largest and most brilliant forms occur. It is noteworthy that the number of genera is very great whereas the number of species in each genus is relatively small. The smallest North American species is *Cyrtinus pygmæus* Haldeman, a brown and whitish, ant-like beetle only

2-3 mm. long. One of the largest species is *Batocera wallacei* Thomson of New Guinea, the body of which may be 80 mm., the antennæ 190 mm., and the fore-legs 85 mm. long.

Mimicry is especially pronounced in this family. Genera that are cryptic include among others certain species of *Monochamus* Guérin, *Synaphæta* Thomson, *Pogonocherus* Zetterstedt, *Graphisurus* Kirby, *Saperda* Fab., *Rhagium* Fab., and *Xylotrechus* Chevrolat. *Ulochætes* Lec. looks like a bumblebee;

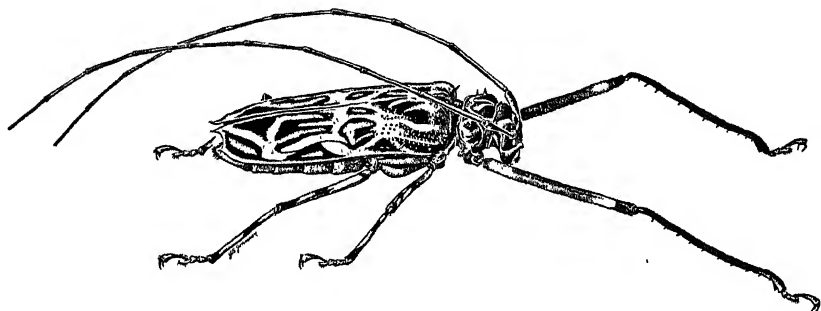


FIG. 202. *Acrocinus longimanus* (Linn.), a remarkable cerambycid beetle with orange and black markings and the fore legs greatly developed. It occurs in the forests of tropical North and South America. Reduced $\frac{1}{4}$.

Sphecomorpha Newm., *Phespia* Bates, *Tomopterus* Serv. (all Neotropical); *Necydalis* Linn., *Cyllene* Newm., *Strangalia* Serville, *Aridæus* Thomson (Australian), and *Hesthesis* Newman (Australian) mimic certain wasps; *Lygesis* Pascoe (Australian) looks like bugs of the genus *Leptocoris* Latr.; *Zoedia* Pascoe (Australian) and *Eudercus* Lec. (North American) mimic ants; and *Formicomimus mirabilis* Aurivillius has an ant-like head. *Oxylymma* Pascoe (South American), mimics cantharids and *Ornistorus* Thoms. (South American) and *Elytroleptus* Dugès (North American) mimic lycids.

Important genera with species common to the coniferous forests are: *Anoplo-dera* Mulsant, *Asemum* Eschscholtz, *Atimia* Haldeman, *Callidium* Fab., *Criocephalus* Muls., *Ergates* Serville, *Graphisurus* Kirby, *Leptura* Linn., *Monochamus* Serv., *Pogonocherus* Latr., and *Prionus* Fab.

Those genera associated primarily with deciduous shrubs and trees are: *Acanthoderes* Serv., *Cerambyx* Linn., *Clytus* Laicharting, *Cyllene* Newman, *Desmocerus* Serv., *Glena* Newm., *Goes* Lec., *Ipochnus* Lec., *Neoclytus* Thomson, *Oberea* Muls., *Oncideres* Serv., *Phymatodes* Muls., *Rosalia* Serv., *Saperda* Fab., *Synaphæta* Thomson, *Xylocrius* Lec., and *Xylotrechus* Chevrolat.

Genera that attack the roots and stems of small annual and perennial plants are: *Agapanthia* Serv., *Brachysomida* Casey, *Coriodera* Muls., *Crossidius* Lec., *Dorcadion* Dalman, *Moneilema* Say, *Phytacia* Muls., *Tetraopes* Latr., and *Vesperus* Latr.

A few of the most interesting and remarkable species not previously mentioned should be included. The beautiful satiny green and gold *Callichroma*

suaveolens (Linn.) is believed by Harvey¹ to be one of the insects involved in constructing Poe's famous "Gold Bug." *C. holochlora* Bates of Central America has a beautiful iridescent green dorsum and black legs and antennæ. The famous harlequin beetle, *Acrocinus longimanus* (Linn.), is a giant species 65 mm. long, with greatly elongated forelegs 75 mm. long and antennæ about the same length. It is velvety black with brown, gray, and reddish brick-colored markings and occurs throughout tropical North and South America, the finest colored specimens occurring in southern Brazil. It was originally described by Linnæus in the genus *Cerambyx* but has since been relegated to at least five other genera. It is figured in a great many books on insects but very little is known about it.

Melanauster chinensis Förster is a shining black species with white dorsal spots and bluish antennal and leg markings. It is 35–40 mm. long and is a favorite of Chinese and Japanese collectors. The Chinese make knitted and wired artificial specimens of it for the trade.

One of the most beautiful species is the superb *Psolidognathus superbus* Fries of Colombia and tropical South America, a brilliant metallic-green sculptured species attaining a length of 50–65 mm. including the long exserted mandibles. The head, thorax, and base of the elytra are spined. *Macrodonia cervicornis* Linn. of Brazil is another huge black, brown, and tan species with very large mandibles, wide truncate elytra, and short antennæ. One of the handsomest and most brilliant genera is *Crioprosopus* Serville, 18 species, of Central America. *Cerambyx cerdo* Linn., a brown and black species 26–50 mm. long, is the largest European species. *Prionus californicus* Motschulsky and *Ergates spiculatus* Lec. are both shining brown species attaining a length of 60 mm. and are among the largest species in temperate North America.

Family CHRYSOMELIDÆ (Leach 1815, 1819) (Chrys'o-mel'i-dæ, from the Greek *σμηλολόνθιον*, a little golden beetle [*χρυσός*, gold, + *μηλολόνθιον*, beetle]; from the brilliant golden colors of many species). German, Blattkäfer, Laubkäfer. Chrysomelid Beetles, Leaf Beetles, Tortoise Beetles, Flea Beetles.

Minute to small, globular, elongated flattened, oval, cylindrical, or slender beetles; hard or leathery, smooth, scaly, pubescent, punctured, or striated; dull or brightly colored in all shades and combinations of rainbow hues; enameled or brilliant, iridescent and metallic. Head small, mostly hypognathous, some prognathous, sometimes partially or wholly covered by the prothorax. Antennæ short, rarely as long as the body, simple or somewhat clavate, 11-segmented (rarely 10-segmented), arising in front of the eyes. Eyes well developed, rounded, often emarginate. Mouth parts inconspicuous, mandibles short and strong. Prothorax variable, narrower than or as wide as the mesothorax. Legs short; hind femora enlarged for jumping in many forms; tibial spurs usually absent; tarsi five-segmented, the fourth very small and hidden. Wings well

¹ Harvey, A. Israfel, *The Life and Times of Edgar Allan Poe* (Doubleday Doran, N. Y., 1927), I:214–219. Also see E. A. Smith, *Sewanee Rev.*, Jan. 1, 1910.

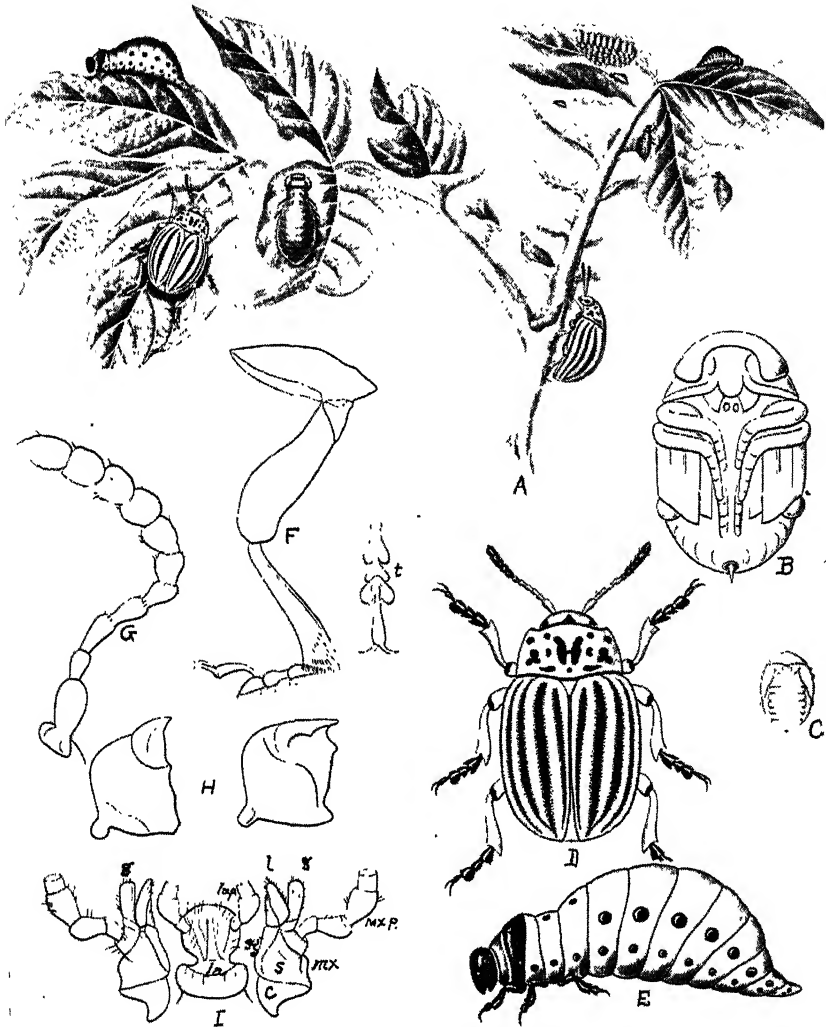


FIG. 203. The Colorado potato beetle, *Leptinotarsa 10-lineata* (Say), an American species now also occurring in Europe. It is one of the most important destructive insects. A, potato plant and various stages of the beetle; B and C, pupæ removed from the soil; D, adult; E, mature larva; F, leg of adult; t, tarsus of same; G, antenna of same; H, mandibles of same; I, a portion of the mouth parts of same; c, cardo; g, glaea; l, lacinia; la, labium; lap, labial palpus; mx, maxilla; mxp, maxillary palpus; s, stipes; sg, subgalea. (From colored chart by T. Fischer, *Insects of Western North America.*)

developed and present in most species. Elytra covering the body, rarely contrasting in color with the rest of the body. Abdomen short, with five visible sternites.

The adults vary in size from *Longitarsus obliteratus* Ross, 1.0–1.3 mm., of Europe, and *Epitrix brevis* Schwarz, 1.5 mm., of North America, to the kangaroo beetle, *Sagria papuana* Jacoby, of Papua, which is 25 mm. long. *Timarcha coriaria* Laicharting, of Europe, may attain a length of 18 mm. The adults are mostly terrestrial but a number of genera are semiaquatic in that they inhabit aquatic plants and the larvæ live in the submerged roots and stems. All forms

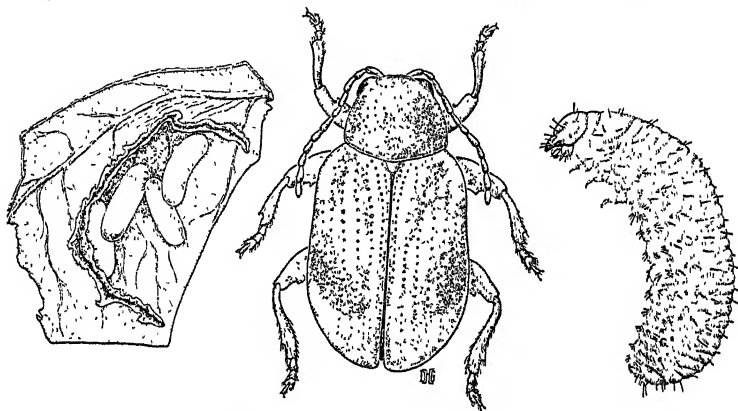


FIG. 204. The strawberry rootworm, *Paria canella* (Fab.). Eggs, adult, and larva. (From *A History of Entomology*.)

are phytophagous and mostly feed on living plants. Some are termitophilous and probably scavengers. The females are largely oviparous but a very few are viviparous. The eggs are laid singly or in clusters on or in the plant tissues or in the soil near the host plants. The larvæ are exceedingly varied in form and color; free-living, plant-inhabiting species, somewhat caraboid in form, and pigmented and often rugose, tuberculate, or spined and some metallic. Secluded and subterranean forms may be subcylindrical, with pigmented head and pronotal shield and the body white or pale yellowish. All are legged and move about freely. Termitophilous forms are usually scarabæoid and are enveloped in smooth cases which first surround the eggs, then are enlarged and carried about and eventually closed for pupation. Larvæ of some of the tortoise beetles have an anal fecal fork which supports a flat roof of fecal material and debris over the body. The larvæ feed exposed on the plants or live in the stems, in galls, in leaf mines, in or on the roots of plants, in ants' nests underground, or rarely in the stems and roots of submerged aquatic plants. Pupation normally takes place in a cell in the ground or in or on the plant tissues. Some aquatic species spin more or less definite cocoons in which to pupate.

The family, one of the four largest of the order, contains approximately 24,000 species. These are widely distributed but are most abundant in the

tropics and reach a high degree of development in tropical America. Cosmopolitan genera include *Cassida* Linn., 263 spp.; *Chrysolina* Motschulsky (*Chrysomela* auct.) 335 spp.; *Crioceris* Geoffroy, 148 spp.; *Cryptocephalus* Geoff., 1,109 spp.; *Cyaniris* Redtenbacher, 193 spp.; *Galerucella* Crotch, 113 spp.; *Lema* Fab., 792 spp.; and *Luperus* Geoff., 232 spp.

Other genera that are widely distributed but are lacking in some continental areas are: *Aspidomorpha* Hope, 137 spp.; *Arthrochalmys* Ihering (*Chlamys* Knoch), 308 spp.; *Colaspis* Fab., 199 spp.; *Coptocycla* Boheman, 105 spp.; *Longitarsus* Latr.; *Metriona* Weise, 176 spp.; *Melasoma* Stephens, 35 spp.; *Monolepta* Erickson, 388 spp.; *Nodonota* Lefèvre, 99 spp.; *Nodostoma* Motschulsky, 241 spp.; *Oides* Weber, 139 spp.; *Pachybrachys* Redtb., 279 spp.; *Paria* Lec., 18 spp.; *Phyllotreta* Foudras; and *Phædon* Latr., 35 spp.

Other genera that are particularly Holarctic are *Adoxus* Kirby, *Altica*¹ Geoff., *Chrysochus* Redtb., *Crepidodera* Chevrolat, *Entomoscelis* Chevrolat, and *Epitrix* Foudras.

Important genera characteristic of North and South America are: *Diabrotica* Chevrolat, 619 spp.; *Glyptoscelis* Lec., 20 spp.; *Leptinotarsa* Stål, 43 spp.; *Monoxia* Lec., 7 spp.; *Palyaspila* Hope, 65 spp.; and *Trirhabda* Lec., 27 spp. Probably the most important species is the Colorado potato beetle, *Leptinotarsa 10-lineata* (Say), which was described from the Rocky Mountain region in 1824 and has since that time become one of the most serious agricultural pests in the world. It probably originated in Central America and has gradually spread northward throughout much of the continent. Its subsequent distribution was greatly hastened by the increase and spread of potato culture, which supports the insect, not only in North America, but now also in parts of Europe where the beetle was introduced and established in 1922.

The twelve-spotted cucumber beetle, *Diabrotica 12punctata* (Fab.), and the striped cucumber beetle, *D. vittata* (Fab.), are common to middle and eastern North America and are replaced in the west by the closely related *D. 11-punctata* Mannerheim (= *soror* Lec.) and *D. trivittata* Mann.

Family LARIIDÆ² Bedel 1891 (Lar-i'i-dæ, from the Greek *λαρινός*, fatted, fat; referring to the short broad bodies of the adults). German, Samenkäfer, Muffelkäfer. French, les bruches. Seed Weevils, Bean Weevils, Legume Weevils, Pulse Beetles.

Small, oval, robust beetles with shortened elytra exposing the tip of the abdomen; body hard, clothed with hairs and scales. Colors brown, gray, black, and

¹ The genus *Altica* was erected by Geoffroy in 1762 and was subsequently accepted by Latreille in 1796. In 1801 Illiger changed the spelling to *Halitica* which latter name has been in general use since that time. According to the rules of priority *Altica* has precedence and *Halitica* is relegated to synonymy.

² There has long been much confusion as to whether the proper family name should be BRUCHIDÆ, MYLABRIDÆ, or LARIIDÆ. The first name used was BRUCHIDÆ, established by Leach in 1819 from the genus *Bruchus* Linnaeus 1767. In looking up the synonymy of this genus, it will be seen that *Laria*, erected by Scopoli 1763, and *Mylabris* by Müller 1764 also refer to these same insects. Since *Laria* Scopoli has priority over the other two, it becomes the type genus of the family LARIIDÆ established by Bedel in 1891. The *Mylabris* of Geoffroy 1762 cannot be considered a valid genus because no species were either

combination of these and white. Head hypognathous, free, small, somewhat produced. Eyes large. Antennæ arising in front of eyes, serrate or pectinate and usually clavate. Mouth parts with well-developed mandibles, palpi, and a stalked mentum. Prothorax prominent, somewhat triangular and usually wider than long. Legs short, hind femora thickened and sometimes with a marginal tooth. Tarsi five-segmented, first elongated and fourth very small. Claws with a basal hook. Elytra smooth or striated, covered with hairs and scales; truncate and shorter than abdomen. Wings usually present. Abdomen robust; five free

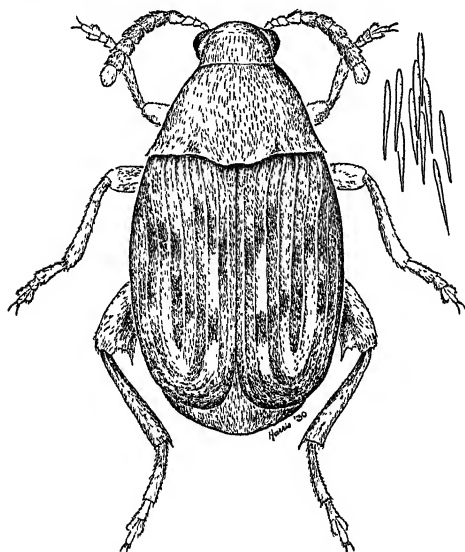


FIG. 205. The bean weevil, *Acanthoscelides obtectus* (Say), and greatly enlarged body scales.

sternites. Larvæ undergo a hypermetamorphosis in which the first stage is more or less caraboid with well-developed legs and spined or toothed thoracic plates to aid in entering the smooth hard seeds. After entering the host the first molt occurs and the body becomes eruciform in most but not all species, and partially or wholly apodous; blind, and white or yellowish in color.

These remarkable insects feed almost wholly upon the seeds of legumes but a very few species have also been reared on the seeds of palms, including the coconut. The adults rarely visit flowers and hibernate in the temperate regions. In the tropics and in heated buildings in

the cooler regions they may remain active and breed throughout much of the year. The eggs are glued to the outside of the pods or seeds or may be laid in the larval and adult burrows within the seeds. The eggs are very conspicuous on black seeds but scarcely visible on white ones.

The life histories may be quite complicated but are usually one of two common types, single brooded and many brooded. Single-brooded forms, like the common pea weevil, oviposit on the pods of green peas. The larvæ, which soon hatch, bore through the pods and directly into the seeds before they become dry and hard. Development in the seeds may continue after harvest and in

listed or described under it, and the genus *Bruchus*, as used by him, referred to cerambycid beetles. (See F. E. Schulze, W. Kukenthal, and K. Heider, *Nomenclator Anim. genera. Pruss. Akad. Wissench.* 1:460, 1926.)

It might be well to point out that there are three families in Zoology which are likely to be confused: LARIIDÆ Bedel 1891 (COLEOPTERA), from the genus *Laria* Scopoli 1763; LARIDÆ (AVES), from the genus *Larus* Linn. 1758; and LARRIDÆ Leach 1815, Stephens 1829 (HYMENOPTERA), from the genus *Larra* Fab. 1758.

storage, and the mature beetles remain within the burrows, which are completely closed by the outer coat of the seed, until the following spring and await the development of the peas in the field until time for egg laying. Thus there is but one brood a year. In the many-brooded types, like the common bean weevil, egg-laying takes place in the field or in storage. In the field the eggs may be laid on or in the pods or on the beans and development is quite rapid. In fact, a complete life cycle may be completed in from 20 to 80 days. Shortly after emergence mating occurs, the females oviposit on the clean or infested seeds, and other generations are soon developed. Under the favorable

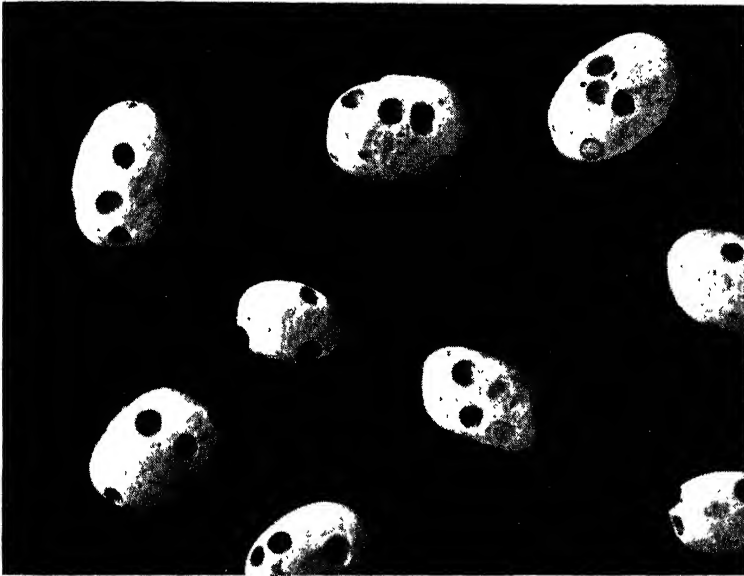


FIG. 206. Common beans showing the exit holes of the bean weevil.

conditions of the tropics or in storage, from four to six broods may arise, and breeding and feeding may continue until the seeds are completely destroyed or until unfavorable conditions such as lack of moisture, too great or too little heat, or other circumstances put an end to development.

The members of this family number no less than 900 species, many of which have become widely distributed through the wide transportation and the extensive use of various kinds of beans, peas, and other legumes. In all there are about 50 species that are of economic importance. While some of them are quite general feeders, all are limited to certain genera and species of the hosts.

The family is constantly undergoing revision and the genera are changed accordingly. Bridwell (1932) has divided the members into four subfamilies and 27 genera, but I am unable to segregate the species into his genera. *Acan-*

thoscelides Schilsky is an American genus that has become widely distributed through commerce. The bean weevil, *A. oblectus* (Say) (*Bruchus*), is one of the most important injurious insects because of its continuous feeding on and breeding in stored beans and cowpeas (*Phaseolus* and *Vigna* spp.) which it destroys both for human consumption and for seed. *Callosobruchus* Pic includes two important species, *C. chinensis* (Linn.) and *C. 4-maculatus* (Fab.) both very destructive to cowpeas (*Vigna*) and now well distributed throughout the world.

Laria Scopoli (*Bruchus* Linn., *Mylabris* Müller) is the largest genus and to it are relegated many important species such as *L. cisti* Fab. (Neotropical, Palearctic); the common and destructive pea weevil, *L. pisorum* (Linn.), now cosmopolitan on peas (*Pisum sativum*); the broad bean weevil *L. rufimanus* (Boheman) (Holarctic) on broad beans (*Vicia faba*); and the vetch weevil, *L. rufipes* Herbst (Palearctic, Oriental) on vetches (*Vicia* spp.); *Zabrotes* Horn, containing the Mexican bean weevil, *Z. pectoralis* (Sharp) (tropical North America), on beans (*Phaseolus* spp.).

C. Suborder RHYNCHOPHORA Billberg 1820

XIX. Superfamily BRENTOIDEA Pierce 1916

XX. Superfamily CURCULIONOIDEA Hopkins 1911

KEY TO IMPORTANT FAMILIES

1. Beak abortive or extremely short and broad; antennæ short with large club; tibiae often with several external teeth; small oval or cylindrical brown or black beetles 2
 Beak well developed; antennæ without or with but a small club; tibiae without external teeth 3
2. First tarsal joint as long as others together; head wider than the prothorax; eyes rounded **PLATYPODIDÆ** p. 604
 First tarsal joint shorter than the combined length of the others; head narrower than the prothorax; eyes oval, emarginate or divided. (Barkbeetles.) **SCOLYTIDÆ** p. 603
3. Antennæ usually elbowed, with the basal joint greatly elongated; palpi small, short, rigid, and nearly always concealed within the mouth; beak often curved downwards. (Weevils.) (Including **RHINOMACERIDÆ**, **RHYNCHITIDÆ**, **ATELABIDÆ**, **BRYSOPIDÆ**, **OTIORHYNCHIDÆ**, **CALANDRIDÆ**.) **CURCULIONIDÆ** p. 599
 Antennæ not elbowed; palpi usually exposed. 4
4. Prothorax elongate, elytra covering the pygidium, first two ventral abdominal segments fused; beak short and broad. . . . **ANTHRIBIDÆ**
 Prothorax not elongate, usually trapezoidal; pygidium exposed; ventral abdominal segments free; beak very long in the female, sometimes entirely absent in the male **BRENTIDÆ** p. 602

Family CURCULIONIDÆ Leach 1817 (Cur-cu'li-on'i-dæ, from the Latin *curculio*, a weevil, a snout beetle). German, Rüssler, Rüsselkäfer. Weevils, Snout Beetles.

Minute to large species characterized by the prolongation of the head with a snout of variable length, width, and shape. Mostly hard, dull-colored or brilliant metallic beetles; shining, smooth, rugose, sculptured, punctured or striated; scaly or hairy; oval, elongated, cylindrical, robust, or long, slender, and even ant-like in form. Head prognathous, globose, slightly or greatly extended, and with mouth parts at the end of the snout. Eyes prominent. Antennæ straight, geniculate, moniliform, clavate, 10- to 12-segmented and with three-segmented club. Snout short and wide or long and decurved; may be grooved for reception of the antennæ. Mouth parts small, strong. Labrum present or absent. Mandibles flat, pincer-like, toothed on one or both sides. Palpi short and usually concealed. Prothorax variable, narrow or as wide as mesothorax. Legs short or very long, fore and middle coxæ rounded, hind pair oval, fore coxal cavities closed behind. Tibiæ sometimes armed. Tarsi five-segmented, simple or pad-like, fourth segment often very small. Claws, usually one pair or may be absent, free or fixed. Wings well developed, rudimentary, or absent. Elytra usually completely covering abdomen but may expose the pygidium. Abdomen with five sternites, the first two fused.

Larvæ curculionoid, *i.e.*, robust, curved, with well-developed head, and apodous. The body may be relatively smooth or wrinkled. Arboreal forms may possess ambulatory process for moving and clinging. Secluded and subterranean forms are pale whereas those exposed to the light are somber-colored and frequently green, in most cases cryptic. The adults and larvæ are phytophagous and feed in or on almost every conceivable part of the plants as root borers, leaf, root, fruit, and seed eaters and leaf miners. Pupation occurs in a cocoon made of fibers of the host or of silk taken from the anus, or in cells in the ground. The pupæ are free. The life histories are variable and correspond in a general way to those of other plant-eating forms. A complete life cycle may require from 4 to 6 months to 1 or several years. All stages may hibernate and the adults frequently also æstivate.

The eggs are usually inserted into the plant tissues. The female first makes a tubular hole, slit, or receptacle with the snout into which the eggs are thrust by means of the elastic and ovipositor-like pygidium.

Parthenogenesis occurs in certain genera as in *Brachyrhinus*. No truly aquatic forms are known although the larvæ of many species live in the roots of plants growing in bogs and marshes, and the adults may dive and swim under water. The adults are nocturnal or diurnal and are usually slow walkers and fliers, but some forms are exceedingly quick on the wing during the heat of the day.

This is probably the largest family of insects and one of the largest groups of closely related living things. It includes approximately 40,000 species which are relegated to no less than 20 subfamilies according to modern workers. Of all the groups of insects this is probably the most difficult to treat in a book of this type since there are hundreds of interesting and important species that one

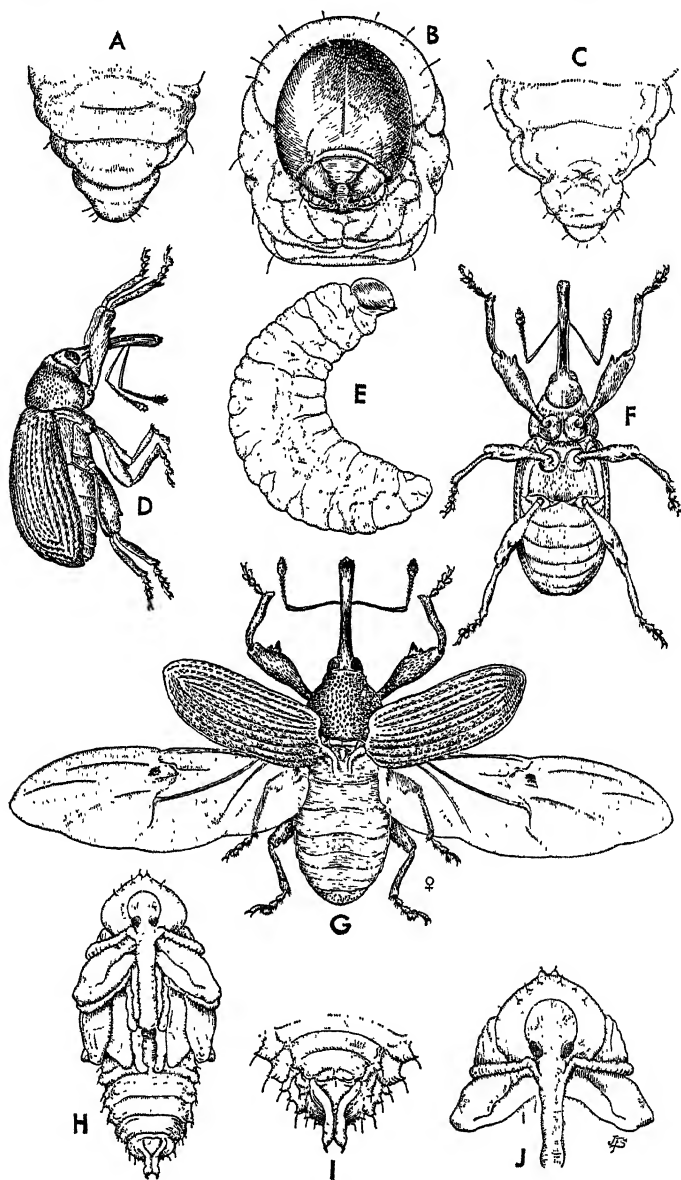


FIG. 207. The cotton boll weevil, *Anthonomus grandis* Boheman, one of the most important economic insects and a native of the New World. A, B, C, E, larva and larval structures; D, F, G, adults; H, I, J, pupa. (After U.S.D.A.)

would like to include. In the arrangement of species I am following Leng's *Catalogue*, so the genera included will not fall in alphabetical sequence.

Rhynchites Herbst with 17 North American species contains the rose snout beetle, *R. bicolor* Fab., 5-7 mm. long, red and black which breeds in wild and cultivated roses throughout much of this country. *Cylas* Latr., 9 spp. (Indo-Malaysian) is now widely represented by the sweet-potato and yam weevil, *C. formicarius* Fab., 3-4 mm., red and blue, and ant-like in form, which is established in some of the southern states. *Apion* Herbst, 1,000 spp., is practically cosmopolitan. It contains some very small species, a few of which are of considerable importance like *Apion pisi* Fab., *A. apricans* Herbst, and *A. flavipes* Paykull of Europe which attack peas, clovers, and other legumes;

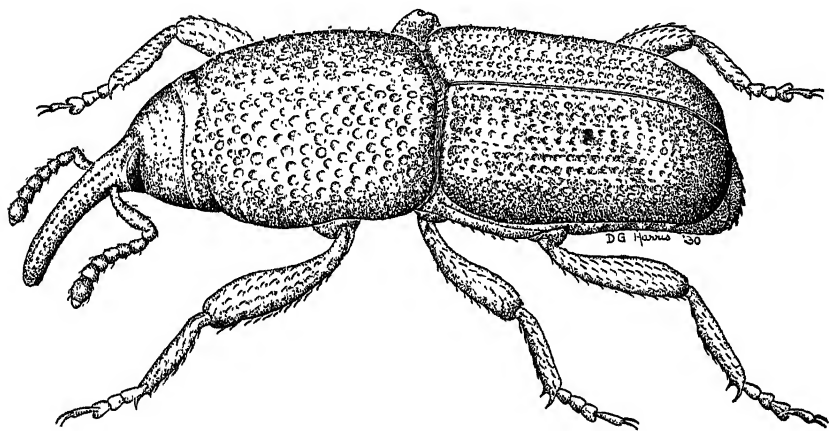


FIG. 208. The rice weevil, *Sitophilus oryza* (Linn.), a cosmopolitan pest of stored cereal products and one of the most important destructive insects known.

A. xanthostylum Wagner on cotton in Africa; and many other economic species throughout the world. There are more than 100 species in North America.

The great genus *Brachyrhinus*¹ Latr. (= *Otiorynchus* Germar), 891 species, is mostly Palearctic, but many economic species have been transferred to other temperate regions; three into Australia and eight into the United States. Many of the species are known to be parthenogenetic. The most important species are: *clavipes* (Bonsdorff), **cribricollis* Gyllenhal, **ligustici* (Linn.), **meridionalis* Gyll., *morio* (Fab.), *niger* (Fab.), *nodosus* Müller, **ovatus* (Linn.), *rufimanus* Hochhuth, **rugifrons* (Gyll.), **rugostriatus* Goeze, **singularis* (Linn.), and **sulcatus* (Fab.) (see Essig, "Economic importance of the genus *Brachyrhinus*," *Mthly. Bull. Calif. St. Dept. Agr.* 22: 397-409).

¹ This and similar generic names as *Otiorynchus* Germar, *Ceutorhynchus* Germar, and *Cryptorhynchus* Illiger were originally spelled as above, but an extra "r" was added and other changes made by subsequent authors which are not in accord with the rules of nomenclature. *Brachyrhinus* Latr. 1802 supersedes *Otiorynchus* Germar 1824.

* These species have been introduced into North America.

Fuller's rose weevil, *Pantomorus godmani* (Crotch), brown, 7-9 mm., is now widely distributed in the Northern Hemisphere. The white fringed weevil, *P. leucoloma* Boheman, was first discovered in Florida in 1936 and has received much publicity as a new pest in North America.

Polydrusus Germar, 186 spp. (Holarctic, Neotropical), and *Naupactus* Schoen., 183 spp. (Neotropical) are large New World genera.

Hypera Germar, 117 spp. (Holarctic and Indo-Australasian), and *Phytonomus* Schoenherr, 114 spp. (Holarctic), have exposed plant-feeding larvæ that spin lace-like cocoons for pupation and include a number of species that injure leguminous crops. Of these the clover leaf weevil, *H. punctata* (Fab.), and the alfalfa weevil, *H. postica* Gyllenhal, are the most important.

Pissodes Germar, 48 spp. (Holarctic). Small weevils attacking coniferous trees. The white pine weevil, *P. strobi* Peck, of North America, is a very important pest of white pines.

Listroderes Schoenherr, 122 spp. (Neotropical). The vegetable weevil, *L. obliquus* Gyllenhal (= *costirostris* Schoen.) has been introduced into Australia, Hawaii, North America, and South Africa. The related genus *Listronotus* Jekel, 31 spp., is North American.

Tychius Germar, 259 spp. (Holarctic, Ethiopian). *Balaninus* Germar, about 50 spp., 26 North American (Holarctic, Neotropical and Indo-Malaysian), includes the common acorn weevils with very long snouts and legs. *Anthonomus* Germar, 327 spp. (cosmopolitan excepting Ethiopia). Many species are serious pests like the apple blossom weevil, *A. pomorum* (Linn.), of Europe, and the cotton boll weevil, *A. grandis* Boheman and the pepper weevil, *A. eugenii* Cano of North and South America. *Cleonus* Schoen., 497 spp., and *Lixus* Fab., 499 spp., are both widely distributed in the Northern Hemisphere. *Ceutorhynchus* Germar, 498 spp., (Holarctic, Indian, Madagascan, Neotropical) contains many very destructive forms. *Conotrachelus* Schoen., 427 spp. (North and South American) contains a number of destructive fruit- and seed-infesting species including the plum curculio, *C. nenuphar* Herbst.

Cryptorhynchus Illiger, 362 spp. (cosmopolitan) contains a large number of economic species including the poplar and willow borer, *C. lapathi* (Linn.), (Holarctic) and *C. assimilis* Paykull and *C. quadridens* Panzer, pests of cruciferous plants, in Europe. *Cossonus* Clairville, 200 spp. (cosmopolitan) and associated with forest trees. *Sphenophorus* Schoen., with over 200 spp. of which 67 are North American, is cosmopolitan with the exception of Ethiopia. It includes many important economic species of weevils commonly called billbugs. *Calandra* Clairville, 158 spp., is truly cosmopolitan as is also *Sitophilus* Schoen., with 17 spp. The two cereal-infesting weevils, the granary weevil, *S. granarius* (Linn.), and the rice weevil, *S. oryza* (Linn.), probably cause the greatest financial losses due to any two insects.

Many genera of this family are well represented by fossils in the Florissant Miocene beds of Colorado.

Family BRENTIDÆ Gerstæcker 1863.

A small family of 900 species characterized by the long narrow bodies and

often also by the extremely long and slender rostrum. Chiefly tropical wood borers but some forms are predacious. (Superfamily BRENTOIDEA.)

Family SCOLYTIDÆ (Latreille 1907) Kirby 1836 (IPIDÆ Ganglbauer 1903)

(Scol-lyt'i-dæ, from the Greek σκολύπτειν, to cut short; referring to the short snout and perhaps also to the truncate body). German, Borkenkäfer. Barkbeetles, Ambrosia Beetles, Shot-hole Borers.

Minute to small, cylindrical, compact bark- and wood-boring beetles which are hard; smooth and shining or dull; rugose, punctate, striate, dentate, and hairy; and mostly black, brown, and mottled in color. Head prognathous or more often hypognathous; small, slightly prolonged into a distinct or obscure snout. Antennæ marginal and in front of the eyes, short, number of segments variable but often 11- or 12-segmented; first segment enlarged, terminal three or four segments greatly enlarged and fused into a compact knob. Eyes large, irregular. Mouth parts small, hidden. Prothorax large, narrower or wider than base of elytra, usually longer than wide, and often narrowest anteriorly. Wings usually well developed for flying. Elytra longer or shorter than the abdomen; rugose, punctate, or striate; normal, truncate or sulcate and dentate or spined posteriorly. Legs short; anterior coxæ contiguous; tibiæ usually dilated and toothed for digging in burrows; tarsi five-segmented, first usually minute, third entire or bilobed. Abdomen short with five or six visible sternites. Larvæ minute, curculionoid; head well developed; apodous; whitish; smooth or slightly hairy; curved.

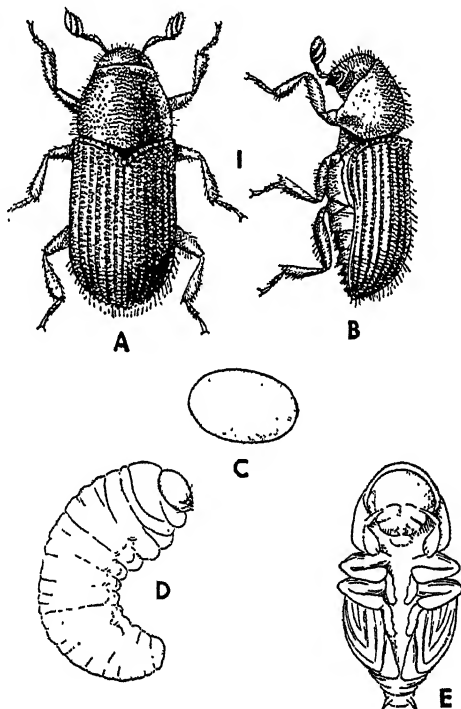


FIG. 209. The peach-tree bark beetle, *Phthorophlaeus liminaris* (Harris), a scolytid beetle occurring in eastern North America. A and B, adults; C, egg; D, larva; E, pupa. (After Brooks, U.S. Bur. Ent., 1916.)

The adults and larvæ live in dead or healthy growing woody shrubs and trees and attack practically all parts of the plants from the roots to the tops. Certain species are often confined to particular parts as roots, trunks, limbs, small branches, and cones or seeds, as well as to different areas of these separate

parts. Some species also attack unhealthy, recently killed, or old wood while others feed only in the living tissues. The heartwood, the growing areas between the wood and bark, and the bark are invaded.

The ambrosia beetles (often separated as the family PLATYPODIDÆ) living in dead wood cultivate fungi to feed their young while in other species wood-rotting fungi assist in the utilization of the wood for food. The species are

monogamous or polygamous; sometimes both sexes aid in constructing the primary gallery and sometimes the work is done only by the fertilized females. The minute white eggs are scattered along the primary galleries, and the larvæ make new tunnels either transverse or parallel to them. In the ambrosia beetles there are indications of a social organization built around the cultivation of fungi for food. Often the burrows form definite patterns which are characteristic of the individual species and aid in their identification.

While many species attack deciduous and broad-leaved trees and shrubs, the greatest damage is done to the coniferous forests of the world. In the United States the annual losses in destruction of timber amounts to \$62,000,000 annually (Doane *et al.*, 1936).

The family is a fairly large one that includes about 2,000 species. It is dominant in the

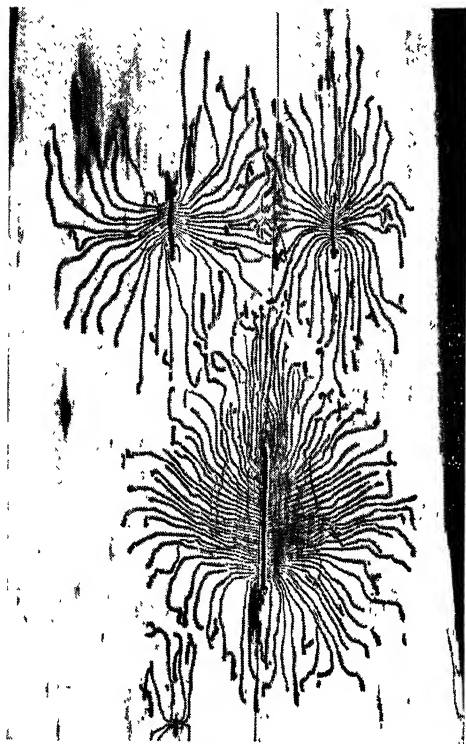


FIG. 210. Galleries of the cypress barkbeetle, *Phlaeosinus cupressus* Hopkins, in the outer sapwood of the Monterey cypress.

temperate regions and is noticeably scarce in Africa. In size the adults vary from the minute *Crypturgus pusillus* Gyllenhal of Europe and *C. atomus* LeConte of North America which are about 1 mm. long to *Dendroctonus micans* Kugelán, one of the commonest European species, and the red turpentine beetle, *D. valens* Lec., one of the most widely distributed American species, which vary from 5-9 mm. in length.

Among the most important genera are the following: *Xyleborus* Eichhoff with 239 spp. is not only the largest, but also the most widely distributed cosmopolitan genus. *Scolytus* Geoffroy, 72 spp., is also cosmopolitan while *Cryphalus*

Erichson (*Stephanoderes* Eichh.), 96 spp., *Dryocates* Eichhoff, 32 spp., and *Hylesinus* Fab., 35 spp., are all widely distributed. Others are *Dendroctonus* Erichson, 24 spp., and *Xyloterus* Er., 11 spp. (Holarctic); *Phlaeosinus* Chapuis, 31 spp. (Holarctic, Neotropical, and Indo-Malaysian); *Phlaeotribus* Latr., 29 spp. (Holarctic, Neotropical, Indian); *Hyurgops* Latr., 5 spp. (Palearctic and Indian); *Eccoptogaster* Herbst, 59 spp., *Hylastes* Er., 51 spp., and *Pityophthorus* Eichh., 64 spp. (Holarctic and Neotropical); and *Gnathotrichus* Eichh., 11 spp., *Micracis* Lec., 8 spp. (Nearctic and Neotropical).

Probably the most important economic species is the western pine beetle, *Dendroctonus brevicornis* Lec., black or dull brown, 4 mm. long, which ranges in the pine forests throughout much of North America. Another almost equally destructive species is the coffee berry beetle, *Cryphalus* (*Stephanoderes*) *hampei* (Ferrari), a native of tropical South America which has been distributed throughout much of the coffee-growing areas of the world and is now one of the most serious pests of coffee in the field and in storage.

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CHAPTER XXXIII

30. Order STREPSIPTERA ¹ Kirby 1813 ²

(Strep-sip'ter-a, from the Greek στρέψις, a twisting, a turning around, + πτερά, wings; referring to the twisted fore wings or elytra of dried male specimens.) German, Strepsipteren, Fächerflügler. French, Strepsiptères.

Strepsipterans, Stylops, Twisted-winged Insects.

Minute to small, free-living and endoparasitic, dimorphic insects with complex metamorphosis and hypermetamorphosis; atrophied biting mouth parts. Males beetle-like, winged, active; eyes conspicuous, protuberant; ocelli absent; antennæ shorter than body, flabellate; metathorax greatly enlarged; fore wings reduced to clavate or paddle-shaped halteres; hind wings large, fan-shaped with few longitudinal veins, folding lengthwise; tarsi two- to five-segmented. Females larviform, head and thorax fused; mouth parts atrophied; eyes, antennæ, palpi, legs, body segmentation, and genitalia absent (present and reduced in family MENGEIDÆ); wings absent. Larvæ dimorphic); primary larva (triungulin) active, free living, campodeiform, spiny, segmented, with vestigial eyes, antennæ, mouth parts, and well-developed legs. Later stages eruciform, segmented, without distinct head, appendages or spines; mouth parts and legs indicated.

IMPORTANT CHARACTERS

<i>Adult Male</i>	<i>Adult Female</i>	<i>Larva</i>
Size — small; 1.5–4.0 mm. long.	free-living forms — 2 mm. long parasitic forms — 20–30 mm. long.	primary larvæ (triungulins) 0.1–0.3 mm. long.
Shape — short, robust, beetle-like.	larviform, elongated, widest in middle, cylindrical or somewhat flattened.	primary larvæ campodeiform or elongated; mature forms eruciform or grub-like.
Color — various shades of brown almost to black.	whitish, yellowish, brownish with darker protruding cephalothorax.	pale, yellow, or various shades of brown.

¹ These very strange insects have had few changes in nomenclature since they were placed in the order STREPSIPTERA by Kirby in 1813. However, a few other designations have been used such as RHIPIDOPTERA in the order DIPTERA Lamarck 1816; RHIPIDOPTERA Latreille 1817; STREPSATA Billberg 1820; RHIPIDOPTERA Burmeister 1829; STYLOPITES Newman 1834; STYLOPIDA Hæckel 1896.

Although they are closely related to the order COLEOPTERA and included in that order by some authors, most entomologists are agreed to their separation into a distinct order.

² The author is greatly indebted to R. M. Bohart for much help in organizing and supplying information for this chapter.

IMPORTANT CHARACTERS—*Continued*

<i>Adult Male</i>	<i>Adult Female</i>	<i>Larva</i>
Integument — hard, heavily chitinized and pigmented; smooth, rough, or hairy; segmented.	thin and elastic, smooth, faintly segmented; delicate.	primary larvæ — chitinized and pigmented; distinctly segmented; bristly. Later forms, smooth and delicate.
Head — well developed; hypognathous; usually wider than long.	usually distinct: small; prognathous; incorporated into cephalothorax; chitinized and pigmented.	well developed, fitting into thorax; usually wider than long; chitinized and pigmented.
<i>Antennæ</i> — well developed; four- to seven-segmented; variable; some segments flabellate, appearing branched; with sensoria.	absent or reduced in family MENGEIDÆ.	primary larvæ — lack well-formed antennæ; present or absent in older forms; with apical bristle. Sensoria may be present.
<i>Eyes</i> — compound eyes large, aggregations of 20 to 50 simple eyes; raspberry-like form, protuberant.	absent or reduced in family MENGEIDÆ.	compound eyes absent.
<i>Ocelli</i> — absent.	absent or reduced in family MENGEIDÆ.	three to five present.
<i>Mouth parts</i> — reduced.	absent or reduced in family MENGEIDÆ.	reduced.
<i>Labrum</i> — reduced or absent.	absent or reduced in family MENGEIDÆ.	reduced.
<i>Mandibles</i> — reduced and bristle-like; simple and sickle-shaped.	a reduced pair.	small; horizontal absent in primary larvæ.
<i>Maxillæ</i> — absent.	absent or reduced in family MENGEIDÆ.	maxillæ and one- to four-segmented palpi.
<i>Maxillary palpi</i> — two-segmented.	absent or reduced in family MENGEIDÆ.	
<i>Labial palpi</i> — absent.	absent or reduced in family MENGEIDÆ.	
<i>Labium</i> — reduced in primitive forms; absent in others.	absent or reduced in family MENGEIDÆ.	present with mentum and submentum.
Thorax — pro- and mesothorax small; metathorax very large, postscutellum greatly enlarged.	cephalothorax — undifferentiated, joined to head; or segments distinct in MENGEIDÆ.	evident; segments similar.

IMPORTANT CHARACTERS—*Continued*

<i>Adult Male</i>	<i>Adult Female</i>	<i>Larva</i>
<i>Legs</i> — fore and middle coxæ long; trochanters absent; tarsi isomerous: two- to four-segmented [five-segmented in the fossil <i>Mengea tertiaria</i> (Menge)]; mostly cylindrical; two claws or none, large pulvillus.	absent or reduced in family MENGEIDÆ.	three pairs in primary larvæ. Tarsi — variable: bristle-like with round or oblong pulvilli. Absent in older forms.
<i>Wings</i> — <i>Fore wings</i> — vestigial, paddle-like or club-shaped; called halteres. <i>Hind wings</i> — large, fan-shaped, venation reduced.	absent.	absent.
<i>Spiracles</i> (thoracic) — one pair mesothoracic one pair metathoracic	one pair present on mesothorax in some species. one pair metathoracic.	not evident.
<i>Abdomen</i> — 10-segmented, base hidden by post-scutellum. <i>Spiracles</i> — six to eight pairs. <i>Genitalia</i> — male ædeagus straight or hooked and in a cavity formed by segments IX and X.	Well developed, unsegmented, sac-like. <i>Spiracles</i> — Free-living forms with seven pair on abdomen. Parasitic forms with one pair on metathorax. <i>Brood passage</i> — the ventral space between the body and the puparium; slit opening between head and thorax of puparium for fertilization and escape of young. <i>Genitalia</i> — absent.	10-segmented, clothed with setæ and bristles and a pair of longer bristles or setæ in primary larvæ. Segmented and nearly devoid of setæ in later stages. <i>Spiracles</i> — none observed.

INTERNAL ANATOMY

The internal anatomy is very imperfectly known. The brain is well developed. There is a ganglionic mass and five pairs of nerves in the thoracic region and another ganglion in the region of abdominal segment III with two pairs of nerves.

In the female the circulatory system is simple and consists of a tubular heart with nine pairs of ostia and an aorta extending to the cephalothorax.

The respiratory system in the mendeid or free-living females consists of a pair of longitudinal trunk tracheæ and a pair of spiracles on each of the mesothorax and metathorax, and seven abdominal pairs. In the parasitic females there is a single pair of spiracles on the metathorax connecting with a pair of trunk tracheæ each of which divides in the first abdominal segment into one or two pairs. The cephalothoracic and abdominal tracheæ may or may not unite to form a complete band or circle.

The digestive system is modified to meet the conditions of the various forms. In the larva the alimentary canal ends in the mid-gut whereas it is complete in the adult males and free-living females. In the parasitic females it is a simple, functionless tube. The adult forms take no food other than by absorption, there is no excretion, and the Malpighian tubes are absent.

Reproduction is sexual although there are evidences of parthenogenesis, and polyembryony may be possible but has not been proved. The males have one pair of ovoid testes. The sperm passes through the seminal vesicle and the short ejaculatory duct to the ædeagus. In the mendeid or free-living females there is a terminal genital opening, but in the endoparasitic forms the ovaries produce great numbers of eggs, and the embryos are free in the abdomen. The hatched larvæ emerge through the funnel-like oviducts of the abdominal sternites.

LIFE HISTORY

The very active flying male locates the parasitic female on the living host and fertilizes it in the region between the head and the thorax. The legion of active primary larvæ escape from the body of the female to that of the parasitized host and from thence to the ground or to flowers or plants visited by the host. The next and most important step is for them to find the larvæ or nymphs of a suitable host upon which to complete the life so soon begun. This step may be accomplished by (1) crawling upon and entering the body cavity of a leaf-hopper, bug, grasshopper, or other similar host, or (2) remaining upon the original host or transferring to another to be carried to the nest and brood of bees or wasps where the primary larvæ enter into the bodies of the host larvæ by means of their sharp chisel-like heads.

Where one primary larva is successful in finding a suitable host, thousands must perish unsuccessfully in the search.

Once established within the body of the host the primary larvæ soon molt and become transformed into the legless, cruciform type. During larval development as many as seven instars are reported for *Stylops*, but little information is available concerning the hidden life of these insects. Nutrition is by absorption and the parasite does not actually invade the tissues but lives free in the body cavity. When mature, the larva protrudes the cephalothorax outside the body of the host through the intersegmental membrane and pupates within its two preceding exuviae.

The male forms an exarate or free pupa within the last larval skin and upon reaching maturity bursts forth from the rounded exposed portion of the puparium on some bright sunny morning and flies away to seek a female on some

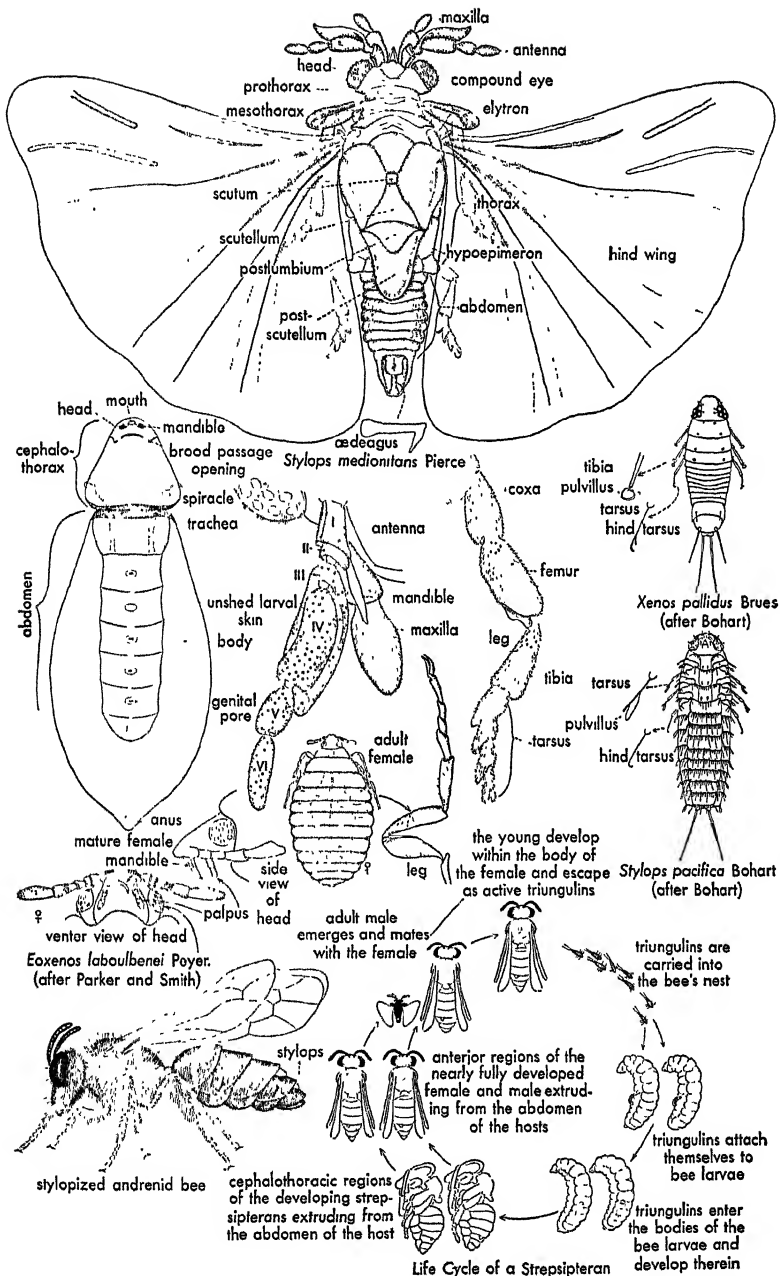


FIG 211. STREPSIPTERA, stylops or twisted-winged insects. Important characteristics and life cycle.

wandering insect host. The exceedingly energetic males have only one or two days in which to find the opposite sex.

The mature females remain sealed in the pupal skin, the flattened cephalothoracic portion of which is exerted between the abdominal segments of the host during development, and perish with the host after the emergence of the young.

Many interesting effects have been observed in connection with the parasitism or stylopization of the hosts. Among these may be mentioned reduction in the size of the head, the sexual organs of both sexes, and the stinging apparatus of the female; enlargement of the abdomen; increase in pilosity; finer puncturation; and a tendency to acquire certain secondary sexual characters, particularly in coloration. The life of the host is not necessarily shortened by the presence of the female stylops, but the male may have a profound and drastic effect upon the host.

The known hosts of stylops, according to Bohart, consist of the following:

Order ORTHOPTERA — three genera.

Order HEMIPTERA —

Suborder HOMOPTERA — 45 genera.

Suborder HETEROPTERA — three genera.

Order HYMENOPTERA — 41 genera.

The fossil records are very imperfect but suggest that these insects are an ancient group. *Mengea tertiaria* (Menge) was taken in Baltic Amber of the Eocene and is the archaic representative of the family MENGEIDÆ having living representatives of three genera and five species.

Strepsipterans are widely distributed, and members of the family STYLOPIDÆ have been collected from all the major geographical regions. Some families are limited to certain continents and others to the very small areas inhabited by the hosts.

The order is composed of some 35 genera and subgenera and approximately 300 species. There are more than 100 described species in North America.

Collecting and Mounting. — The adult males may be taken in the ordinary pursuit of insects by sweeping and beating various forms of vegetation, but the most important source of these obscure insects is through the hosts. This search requires a thorough knowledge of host specificity as well as an understanding of the taxonomy and biology of the hosts. Stylopized hosts may be segregated and the stylops removed or reared from the same.

The males may be mounted on points as are beetles, but the primary larvæ and females are best studied and preserved as cleared specimens mounted permanently in balsam on microscopic slides. Clearing in KOH or lactic acid and staining the transparent forms give very remarkable results.

CLASSIFICATION

The classification of these insects is difficult because of the lack of information as to the immature and adult stages.

The first male recorded by P. Rossius in 1793 was taken from the wasp

The classification is modified from that of Pierce, Ulrich, and Bohart. I am following many modern workers in substituting the term "primary larva" for "triungulin."

- | | | |
|--|-------------------------|--------|
| 1. Tarsi five-segmented and with paired claws | MENGEIDÆ | p. 616 |
| Tarsi with less than five segments and without claws | 2 | |
| 2. Tarsi four-segmented | 3 | |
| Tarsi two- or three-segmented | 5 | |
| 3. Antennæ seven-segmented; segment IV short; V-VII very long | | |
| | MYRMECOLACIDÆ | p. 616 |
| Antennæ with less than seven segments | 4 | |
| 4. Antennæ five-segmented; segments III and IV laterally flabellate; tarsal
segment I equals II-IV combined | CALLIPHARIXENIDÆ | p. 617 |
| Antennæ five-segmented; segment III only laterally flabellate; tarsal
segment I shorter than II-IV combined | STYLOPIDÆ | p. 617 |
| 5. Tarsi two-segmented; antennæ four-segmented; segment III laterally
flabellate, flabellum originating at base | ELENCHIDÆ | |
| Tarsi three-segmented; antennæ seven-segmented | HALICTOPHAGIDÆ | p. 617 |

- | | | |
|---|-------------------------|--------|
| 1. Adult free living, larviform, with legs, antennæ, and eyes | MENGEIDÆ | p. 616 |
| Adult partly endoparasitic, without legs, antennæ, and eyes | 2 | |
| 2. Cephalothorax with hook-like projections behind the spiracles (para-
sitic on TETTIGONIIDÆ) | STICHOTREMATIDÆ | p. 618 |
| Cephalothorax without hook-like projections | 3 | |
| 3. Cephalothorax greatly elongated; two pairs of spiracles; or with seg-
ments of thorax distinct (parasitic on HEMIPTERA-HETEROP-
TERA) | CALLIPHARIXENIDÆ | p. 617 |
| Cephalothorax with a single pair of spiracles; thoracic segments com-
pletely fused | 4 | |
| 4. Parasitic on HEMIPTERA-HOMOPTERA and GYRLIDÆ | HALICTOPHAGIDÆ | p. 617 |
| Parasitic on HYMENOPTERA or FULGORIDÆ | 5 | |

¹ They were in fact discovered by A. Laboulbène in France in 1870 and the species was named for him.

5. Abdomen with five genital tubes (parasitic on aculeate HYMENOPTERA) **STYLOPIDÆ** p. 617
 Abdomen with three genital tubes (parasitic on FULGORIDÆ) **ELENCHIDÆ**

KEY TO FAMILIES — LARVÆ

(After R. M. Bohart)

1. Fore and middle tarsi pulvilliform, hind tarsi setiform 2
 Middle tarsi setiform 5
 2. Head with two long backward-projecting bristles ventrally 3
 Head without long bristles (parasitic on SPHECOIDEA, VESPOIDEA, and APOIDEA) **STYLOPIDÆ** p. 617
 3. Abdominal sternites with posterior margins dentate but without bristles (parasitic on HEMIPTERA-HETEROPTERA) **CALLIPHARIXENIDÆ** p. 617
 Abdominal sternites with bristles on posterior margins 4
 4. All tarsi setiform (parasitic on FULGORIDÆ) **ELENCHIDÆ**
 Fore and middle tarsi pulvilliform, hind tarsi setiform (habits unknown) **MENGEIDÆ**
 5. Fore tarsi pulvilliform; middle tarsi short and setiform (parasitic on TETTIGONIIDÆ) **STICHOTREMATIDÆ** p. 618
 All tarsi long and setiform (parasitic on HEMIPTERA-HOMOPTERA and GRYLLIDÆ) **HALICTOPHAGIDÆ** p. 617

Family MENGEIDÆ Pierce 1908 (Men-ge'i-dæ, named for Anton Menge who published a paper that included these insects under the generic name *Triæna* in 1866. This genus, being preoccupied by *Triæna* Hüber 1818 in LEPIDOPTERA, was changed to *Mengea* by Grote in 1886) (MENGENILLIDÆ).

These are the most primitive members of the order and the most unspecialized. The oldest known species of the order, *Mengea tertiaria* (Menge), is a Tertiary insect taken from the Eocene in German Baltic Amber. The males have two claws, cylindrical tarsal segments, and six-segmented antennæ.

In the existing living forms the females are larviform and free living, having been found under stones and tree trunks. Nothing is known concerning their biology. The males have a simple (not hooked) ædeagus and six or seven-segmented antennæ of which at least the third and fourth are flabellate. The tarsi of both sexes have terminal paired claws.

The known living genera are *Mengenilla* Hofeneder with six species and *Eoxenos* Peyerimhoff and *Triozocera* Pierce, each with one species. The distribution includes northern Africa (Mediterranean region), North America, and Australia.

Family MYRMECOLACIDÆ Saunders 1872 (Myr'me-col-ac'i-dæ, from the Greek *μύρμηξ*, *μύρμηκος*, an ant, + *λακίξω*, to tear; from the parasitism of ants).

A small family with two important genera, *Myrmecolax* Westwood and *Cænocholax* Pierce, occurring in Mexico and southern Asia. Females unknown. Recorded as parasitic on ants.

Family STYLOPIDÆ Kirby 1813 (Sty-lop'i-dæ, from the Greek στῦλος, a pillar, + ὤψ, ὀψός, the eye; referring to the protuberant eyes).

One of the two important families of strepsipterans.

The adult males have four-segmented tarsi, small prescutum, and an elongated postscutellum. The members are widely distributed and consist of about 165 described species in North America with a great many other species in the Palearctic region. They are parasitic on bees. The important genera are *Stylops* Kirby, *Neostylops* Pierce, *Xenos* Rossius, *Pseudoxenos* Saunders, *Crawfordia* Pierce, *Halictoxenos* Pierce, *Hylecthrus* Saunders, and *Pseudostylops* Bohart.

Important North American species are:

Stylops salicifloris Pierce. Female with cephalothorax 1.01 mm. long and as wide. It is a common species on the Pacific coast and is parasitic on the andrenid bees, *Trachandrena* spp. *Stylops medionitans* Pierce is common and parasitic on the bees, *Andrena* spp., in western North America. *S. pacifica* Bohart and *S. van dykei* Bohart are both parasitic on the bees, *Andrena* spp., on the Pacific coast.

Stylops melittæ Kirby 1802 and *S. kirbii* Leach 1817 were first discovered in England. The former occurs throughout northern Europe. *Xenos vesparum* Rossi 1793 (*X. rossi* Kirby), parasitic on *Polistes gallicus* Linn., is reported from Europe and Egypt. *Xenos peckii* Kirby 1813 was the first species described from North America. Specimens of males were collected in Massachusetts on *Polistes fuscatus* Fab. by W. D. Peck who sent them to Kirby under the name of *Xenos vespæ*.

There are 21 species (Ulrich, 1930) of *Stylops*, two species of *Neostylops*, three species of *Hylecthrus*, nine species of *Halictoxenos*, one species of *Xenos*, and five species of *Pseudoxenos* in Europe.

Family HALICTOPHAGIDÆ Perkins 1905 (Ha'lic-to-phag'i-dæ, from *Halictus*, a genus of small bees, + φαγεῖν, to eat; parasitic on *Halictus*.)

This is one of the two largest families of the order and with the family STYLOPIDÆ constitutes three fourths of the known species. The seven-segmented compact or elongated antennæ and the three-segmented tarsi serve to characterize the adult males. The members are parasitic on HEMIPTERA-HOMOPTERA and on GRYLLIDÆ.

Family CALLIPHARIXENIDÆ Pierce 1918 (Cal'li-phar'ix-en'i-dæ, from the Greek κάλλος, beauty, + φερέω, to have, + ξένος, stranger; literally from a genus of bugs, *Calliphara*, + *Xenos*, a genus of the family STYLOPIDÆ; parasites of scutellerid bugs).

A small family having two common genera, *Callipharixenos* Pierce and *Corioxenos* Blair. The members are parasitic on bugs of the families SCUTELLERIDÆ and PENTATOMIDÆ and have been taken in Africa and Thailand.

Family STICHOTREMATIDÆ Hofeneder 1910 (Stich'o-tre-mat'i-dæ, from the Greek *στίχος*, a line, a row, + *τρήμα*, *τρήματος*, a hole; referring to the rows of abdominal genital tubes). Orthopteran parasites.

A very small family with one important genus, *Stichotrema* Hofeneder, which is parasitic on the orthopteran, *Sexava* sp., in Dutch New Guinea.

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CHAPTER XXXIV

31. Order HYMENOPTERA Linnæus 1758

(Hy'men-op'ter-a, from the Greek *ὕμην*, a thin skin, membrane, + *πτερά*, wings; in reference to the naked membranous wings.) German, Hautflügler. French, Hyménoptères.

Ants, Bees, Wasps, Gallflies, Sawflies, Horntails, Ichneumons, Braconids.

Minute to medium-sized insects with complex metamorphosis and specialized mouth parts for biting, chewing, lapping, and sucking. Ocelli generally present. Antennæ normally 12-segmented in male and 13-segmented in female. Tarsi normally five-segmented. Apterous or with two pairs of stiff, naked, relatively narrow, membranous wings; fore pair much the larger; venation reduced or rarely absent; stigma usually present. Abdomen nearly always with basal pedicel; generally with six or seven visible segments; basal segment fused with thorax. Female with conspicuous ovipositor, which may be modified into a saw, drill, or sting. Larvæ with or without well or poorly-developed head; apodous or with thoracic legs and abdominal prolegs. Pupæ free or exarate and may be enclosed in silken or parchment-like cocoons, herbivorous or parasitic. Many groups with highly developed social organizations. One of the largest¹ and highest orders of insects.

EXTERNAL ANATOMICAL CHARACTERS

Size — varying from the minutest insect known, *Alaptus*, 0.21 mm. long, to robust and bulky bumblebees and very long slender parasitic forms or ichneumons measuring 75–115 mm. in length including the very long ovipositor.

Color — exceedingly variable but including vast numbers of somber shades as well as countless brightly colored, metallic, and iridescent species, many of which have mimetics in other orders.

Integument — parchment-like, leathery, and often strongly chitinized; smooth, pitted or rugose, hairy or pubescent.

Shape — greatly varied; normally somewhat cylindrical and robust to very slender; many with base of abdomen constricted or petiolate, the first segment (propodeum or epinotum) of which may be fused with the metathorax.

Vestiture — naked or clothed with soft pile or long hairs and with spines, setæ, and groups of bristles; hairs of certain bees plumose.

Head — prominent, remarkably free, and with small neck; generally transverse, *i.e.*, wider than long; sometimes nearly globular; and rarely longer than wide in the ants.

¹ While the COLEOPTERA still contains more described species, there are so many minute and obscure forms in this order awaiting description that the HYMENOPTERA may possibly become the larger of the two. Up to the present time at least 120,000 described species are known as against 250,000 in the COLEOPTERA.

Antennæ — variable, generally longer and more modified in the male, which is usually 13-segmented, than in the female, which is normally 12-segmented; filiform, moniliform, clavate, pectinate, flabellate, ringed, verticillate, or geniculate, and usually with a scape, pedicel, and a flagellum; number of segments in series of three to four, 12 to 13, or 14 to 70.

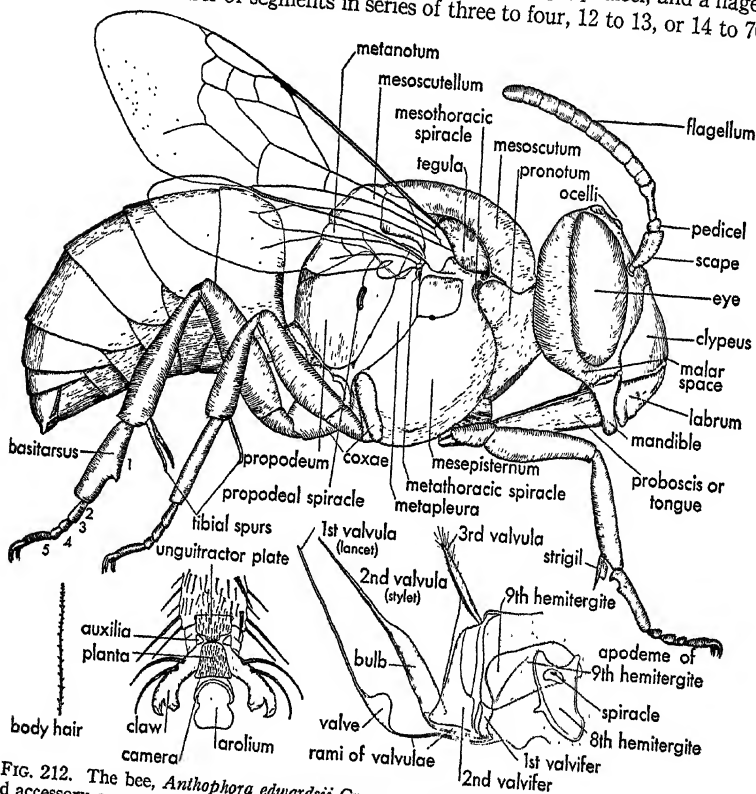


FIG. 212. The bee, *Anthophora edwardsii* Cresson. Drawings of adult male and the sting and accessory organs of the female to show the important characters used in classifying bees. (Drawing by C. D. Michener.)

Eyes — usually very well developed and large; wide apart and often occupying much of the head (holoptic); atrophied or reduced to a single facet in certain ants.

Ocelli — normally three are present in a triangle on the vertex; abortive or absent in the bembicid wasps and some worker ants.

Mouth parts — mandibulate for biting, chewing, mining, cutting, scraping, sucking, and lapping; exceedingly highly specialized. Varying from the typically biting type in the phytophagous forms with strong dentate mandibles, well-formed maxillæ with six-segmented palpi, labium with

differentiated mentum, submentum, cleft three-lobed ligula, and four-segmented palpi, through various modified types to the sucking and lapping bees which also retain the mandibles and have the glossa and associated members variously developed and lengthened to form a proboscis or tongue for collecting nectar of flowers. There is a marked degree of change in all the different organs involved in feeding. They are usually folded beneath the head at rest.

Mandibles — always present, well developed for cutting, biting, chewing, scraping; broad, simple, or toothed.

Maxillæ — variable and quite prominent. *Palpi* — one-, two-, four-, or six-segmented; short and vestigial in the long-tongued bees.

Cardines — well-developed chitinized rods connecting the labium to the head. *Stipites* — narrow basal part of the maxilla which may be fused with the palpiger. *Lacinia* — distinct or atrophied.

Galea — one- or two-segmented lobes. *Cardo* — stalked.

Labium — well developed and quite variable within the order; often greatly attenuated. *Mentum* — of many shapes but often wide, shield-like, and heavily sclerotized. *Submentum* — small or well developed. *Larum* — a thickened band connecting the cardines is present. *Ligula* — a three-cleft lobe or a greatly lengthened part of the sucking mouth parts.

Glossa — (thought to be the *hypopharynx* by some authors) short, broad, simple or bifid, or very greatly elongated and grooved and forms the most conspicuous part of the proboscis or tongue in bees; may exceed the length of the body in *Euglossa*; extended by blood pressure and held beneath body at rest. *Labellum* — the small spoon-shaped or disk-like tip of the glossa in bees. *Paraglossa* — absent, vestigial, small and lobed, or attenuated. *Palpi* — two- to four-segmented, short or greatly lengthened and slender. *Palpiger* — may also be attenuated. The galea, labial palpi, and glossæ are all greatly lengthened into a tongue or proboscis in the long-tongued bees and the maxillæ and labrum are hinged so as to permit withdrawal and folding beneath the head.

Thorax — conspicuous and exceedingly variable in shape, usually remarkably free, except that the basal abdominal segment is fused to the metathorax; normally as wide as the abdomen; frequently humped dorsally owing to large muscular lobes; separated into a number of definite sclerites by well-defined sutures.

Prothorax — generally small, sometimes almost vestigial; frequently narrow and neck-like, and with the pronotum attached to the front of the mesothorax.

Mesothorax — usually very large and with prominent muscular lobes which may form a conspicuous hump on the dorsum, the pleural plates fused into the *prepectus* or *epicnemium*; the mesonotum is divided into the

anterior *scutoprescutum* and posterior *scutellum*; *parapsides*, *tegulae*, and *axillae* are lateral sclerites in certain forms.

Metathorax — somewhat smaller and fused with the *propodeum* or first abdominal segment in the suborder APOCRITA (the fused thorax and propodeum is known as the *alitrunk*); *phragmata* or *endotergites* (apodemes) are often pronounced.

Wings — absent, atrophied, or well developed; two pairs, fore pair much larger than hind pair; relatively narrow; stiff and membranous; naked or with microtrichia; coupled by means of *hamuli* or hooks of hind wing which engage a fold near the median posterior margin of the fore wing, hamuli in series in a row of only two or three, or wholly absent; folded flat over the back at rest; prominent *stigma* or *pterostigma* in the fore wings of many species. *Venation* — highly specialized, mostly by reduction and fusion; with few longitudinal and cross veins, with a single vein in the subcostal region of the fore pair which is absent in the hind pair; and veins may be entirely absent in both pairs. There are a number of systems of wing venation, the three most important being (1) the Old or Jurinian System devised by the French entomologist L. Jurine in 1820, (2) the Comstock-Needham System, 1898–1899 (see also Comstock 1918), and (3) the New or European System now generally used in Europe. Tillyard (1926, p. 258) compares and discusses these systems. Wings absent in both sexes of a few species of DIAPRIIDÆ and ICHNEUMONIDÆ. Females apterous in all workers and some sexuales in FORMICIDÆ, in all MUTILLIDÆ, MYRMOSIDÆ, and THYNIDÆ, and frequently in the BRACONIDÆ and ICHNEUMONIDÆ. Males apterous in certain FORMICIDÆ and CALLIMOMIDÆ.

Legs — usually slender and well formed; the three pairs similar; variable in length and structure for running, jumping, nest building, digging, carrying pollen, and grasping and holding prey. *Trochanters* — simple or two-segmented in certain parasitic forms. *Femora* — large and strong and greatly thickened in certain jumping chalcid flies and other groups. *Calcar* or *spur* is a prominent feature at the apex of the fore tibiae in a number of species and acts with a toothed invagination of the base of the tarsus as a comb or *strigilis* to clean the antennae. In most nectar- and pollen-gathering bees the posterior tibia is dilated and furnished with special hairs to act as a pollen basket or *corbicula* and the metatarsus is flattened and studded with short stiff bristles on the inner side which form a brush or *scopa* used for removing pollen from the body to the pollen basket. Large specialized spurs may also occur on the hind tibiae. *Tarsi* — normally five-segmented; rarely two- or three-segmented in certain parasites. *Metatarsus* of hind legs may be greatly enlarged and widened in pollen-gathering bees. Two simple or dentate *claws* and a single *empodium* present.

Spiracles — a pair present on the membrane between the pro- and mesothorax.

Abdomen — variable in size and form; short and somewhat triangular, oval, or cylindrical and either normal or exceedingly long and slender in parasitic forms. Normally 10-segmented; from four- to nine-segmented or usually six-segmented in the females and eight-segmented in the males of the higher APOCRITA. The first segment or propodeum fused with the metathorax; simple or divided. Second segment in SYMPHYTA broad and normal whereas in the APOCRITA it is constricted into a *pedicel*, *pedicellus*, or *petiole* which is particularly well developed in the ants and wasps. The enlarged abdomen behind the petiole is called the *gaster*. Usually but three to six segments are visible dorsally in the gaster of the higher groups.

Ovipositor — a unique and highly specialized appendage for boring, piercing, and sawing, and also used for oviposition and stinging, for killing and paralyzing and preserving living insect food, and for defense and offense. The ovipositor for egg laying is remarkably developed for particular purposes, may arise from either the base or the tip of the abdomen or from between these points, and is composed of three pairs of appendages or *gonapophyses*: *stylets*, *stylet-sheath*, and *processes*. The *sting* is a modified ovipositor composed of stylets or lancets fitting together to form a hollow piercing *terebra* and *stylet-sheath* with poison sac and basal plates. All types of ovipositors are exceedingly long in certain species which parasitize wood-boring SIRICIDÆ. Special poison or other glands are associated with forms ovipositing in living tissues as well as in stinging species. The *stylets* may be modified into *saws* and *spears* for inserting eggs into plant tissues. An adequate description of these complicated organs should be sought in a comprehensive work on insect anatomy.

Males — genitalia partly concealed; consist of claspers or *gonocoxites* of segment IX and *ædeagus* composed of *penis* and *parameres*. Minute simple or segmented *cerci* may be present. *Spiracles* — usually eight pairs are present, one pair on the propodeum and one each on the seven succeeding segments; one pair on segments I and VIII respectively in certain parasitic chalcids. *Ædeagus* — simple, centrally located; with lateral or terminal processes; two-segmented *phallobase* with processes encircling the *ædeagus*. *Parameres* — lateral ventral and dorsal pairs of movable lobes of the *phallobase*; the *ventral* pair called *volsellæ* and the dorsal pair *squamæ*. *Sagittæ* — proximal lateral processes of the *ædeagus* in APIDÆ. *Spathæ* — dorsal lobes of the *ædeagus* in APIDÆ which cover the bases of the sagittæ.

Eggs — normally elongate-oval and frequently with a tube of variable length, shape, and diameter at one end; smooth and usually without sculpturing of any kind. Deposited singly on or in the host or arranged in great masses.

Larvæ — in the CHALASTOGASTRA (SYMPHYTA) the larvæ are caterpillar-like in size, shape, and general structure, even in vestiture and in ability to spin silken webs over the host plants. They are mostly cylindrical, strongly annulate and often tuberculate, and with setæ and

hairs (depressed in leaf miners). They curl into a spiral at rest or remain attached to the host by means of the prolegs and with the posterior portion of the body suspended above. Head large; heavily chitinized;

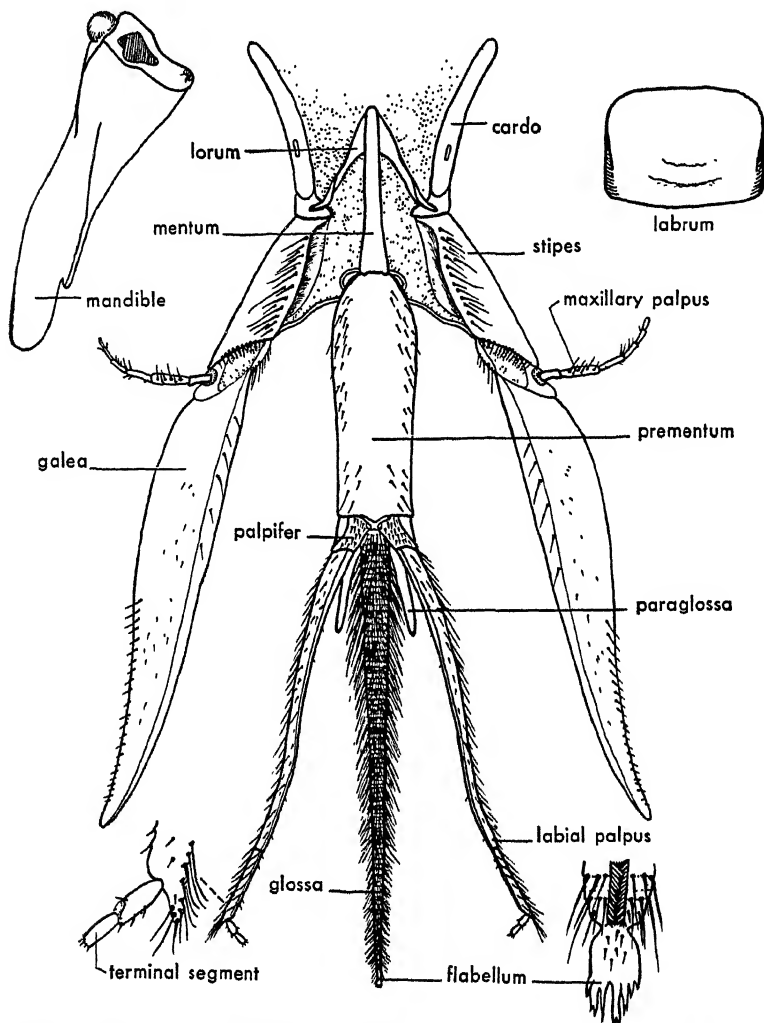


FIG. 213. Mouth parts of *Anthophora edwardsii* Cresson. (Drawing by C. D. Michener.)

smooth; with strong, biting mouth parts, one- to five-segmented antennæ; and with palpi and one to three pairs of ocelli present or absent. Usually with three pairs of four- to five-segmented thoracic legs and frequently with six to 10 pairs of simple segmented prolegs on segments

II to IX and X or absent on VII and VIII, or X. Abdomen may have ventral eversible glands. The wood-boring forms are apodous; cerci present or absent; free living on the host plants or in fruits, leaf rolls, mines, stems, or galls.

In the CLISTOGASTRA or higher forms the larvæ are highly specialized for a particular environment, and some are subject to strict and precise care. These specializations consist chiefly in reduction of parts and the larvæ appear to be an undifferentiated mass enclosed in a thin skin; being apodous, often headless, and usually without appendages or external organs of any kind.

Pupæ — free; often enclosed in a thin parchment-like cocoon or in closed cells of variable structure above or below ground.

IMPORTANT INTERNAL ANATOMICAL FEATURES OF THE ADULTS

Alimentary Canal.

Mouth cavity — variable and often large; leads into the pharynx.

Infrabuccal cavity or chamber — in ants a bag-like sac below the floor of the mouth which retains and rejects solid matter after the juices are strained into the mouth (Imms).

Salivary glands — well developed; one pair in head and one pair in the thorax of bees — four ducts open on the hypopharynx; a mandibular gland also may be present in certain bees and wasps.

Œsophagus — narrow and tube-like; long or short; dilated into a honey stomach in bees.

Crop — greatly extended to serve as a honey reservoir and fills and expands the gaster in honey ants.

Proventriculus — a narrow passage between the crop and the stomach characteristic of the order; with valves and pump action in the honeybee to force the nectar into the stomach.

Stomach or ventriculus — atrophied or small in certain forms, or very large and U-shaped in *Vespa* and *Apis*.

Peritrophic membrane — usually wanting, perhaps because of extensive liquid foods.

Ileum — small intestine — short and simple or long and looped.

Malpighian tubes — exceedingly variable in number: 6–20 in ants, 20–25 in sawflies, 20–30 in leaf-cutting bees, 50–60 in most ichneumon flies; 100 or more in bees; and 100–125 in many wasps; separate or in two to four groups or bundles; open separately into the ileum.

Rectum — large chamber with *rectal papillæ*: three in ants, four in certain ichneumons, and six in the honeybees and in most other members of the order.

Circulatory System. Heart and aorta may be well developed and with four or five chambers in abdominal segments III to VI in the honeybees and IV to VIII in the ants.

Nervous System. The nervous system has been extensively studied and described.

Brain — characterized by the highly differentiated stalked lobes or *mushroom bodies* and nerve fibers of the *procerebrum*, which are not so extensively developed in other arthropods; most highly developed in the common wasps of the genus *Vespa* in which the *calyces* or crowns of the mushroom bodies are folded.

Ventral cord — moderately specialized with from two to three thoracic and from one to nine abdominal ganglia; in certain cases some of the latter may be fused, especially in the males.

Reproductive System.

Female — *ovaries* polytrophic; a variable number of ovarioles: from none or one to 250 in each ovary. *Oviducts* — a pair unite to form the vagina. *Vagina* — may be enlarged posteriorly to form the *bursa copulatrix*. *Spermatheca* and a pair of *colleterial glands* usually present; the former especially well developed in the queen honeybees.

Male — *testes* — usually fused together in most forms but separate in the CHALASTOGASTRA and in the bumblebees and honeybees; each with double membrane and may contain from one to 250 or 300 *seminiferous tubuli*. *Vas deferens* dilated to form cylindrical or globular *vesiculæ seminales*. Two *ejaculatory canals* and a pair of sac-like ducts of the *accessory glands* are present. The former are greatly reduced in the honeybee, in which case the accessory glands empty into the common ejaculatory duct or *ductus ejaculatorius* (Imms, 1934). The sperm of HYMENOPTERA appear to be only female-producing and only this sex is born as a result of mating, males being the product of unfertilized eggs.

FOSSIL HISTORY

The immediate ancestors of the HYMENOPTERA are thought by Tillyard (1926) to be the PROTOHYMENOPTERA of the Lower Permian of Kansas, but Carpenter and other writers do not agree to this ancestry even though an ovipositor is present in the genus *Asthenohymen*. The order appears late in fossil history, the earliest true forms having been taken in the Upper Jurassic. Remains of the primitive so-called false wood wasps or horntails of the genus *Pseudosirex* are plentiful in Bavaria and in the Middle and Lower Purbeck¹ beds of England, and the ichneumon genus *Ephialtites* is found in the Upper Jurassic stones of Montsech, Spain. Cynipids occur in the Canadian Amber of the Cretaceous (Kinsey 1937) in which also have been discovered representatives of the superfamilies ICHNEUMONOIDEA, SERPHOIDEA, and CHALCIDOIDEA (Brues 1937). Other important relatives have also been

¹ Purbeck rocks include fresh-water clays, shales, shell-bearing marls, chert, and oölitic and sandy strata. The so-called marbles containing many fossil shells and remains of other animals have been extensively used as building materials, especially for pillars, in the great cathedrals and churches of Great Britain.

taken in various parts of the world. Aculeate forms first appear in the Eocene and many parasitic forms occur in the Green River Shales and nearly all families are to be found in Lower Oligocene. Practically all castes of ants are recorded from Tertiary with complete differentiation in the Pleistocene.

KEY TO SUBORDERS

1. Base of abdomen broadly joined to the thorax; trochanters always two-segmented; hind wings with three basal cells. Larvæ with thoracic and usually abdominal legs. Phytophagous. (Sawflies, Horn-tails, etc.) **CHALASTOGASTRA**
- Base of abdomen constricted (abdominal segment II); trochanters one- or two-segmented; hind wings with two or fewer basal cells. Larvæ apodous; parasitic, phytophagous, omnivorous. (Bees, Ants, Wasps, Gallflies, etc.) **CLISTOGASTRA** p. 636

A. Suborder CHALASTOGASTRA¹ Konow 1897

(Chal-as'to-gas'tra, from the Greek *χαλαστικός*, loose, + *γαστήρ*, *γαστήρ*, stomach or belly; referring to the abdomen.) Phytophagous forms.

KEY TO SUPERFAMILIES

1. Antennæ inserted below the eyes, clypeus, and frontal ridge; propodeum undivided; ovipositor thread-like and coiled within the body. (Parasitic Wood Wasps.) **ORUSOIDEA** p. 635
- Antennæ inserted between the eyes and above the base of the clypeus; propodeum divided near the middle; ovipositor never coiled; saw-like or spear-like for inserting eggs into plant tissues **2**
2. Fore tibiae with one apical spur. (Horn-tails.) **SIRICOIDEA** p. 633
- Fore tibiae with two apical spurs. (Sawflies.) **TENTHREDINOIDEA**

I. Superfamily TENTHREDINOIDEA MacGillivray 1906

(Ten'thre-din-oi'de-a, from the Greek *τενθρηδών*, a kind of wasp; according to Aristotle, a kind of wasp that makes its nest in the earth.) Sawflies.

LIST OF FAMILIES

- | | |
|--|--------------------------|
| 1. Family XYELIDÆ | 5. Family PERGIDÆ |
| 2. " PAMPHILIIDÆ | 6. " ARGIDÆ (HYLOTOMIDÆ) |
| 3. " MEGALODONTIDÆ | 7. " BLASTICOTOMIDÆ |
| 4. " CIMBICIDÆ | 8. " TENTHREDINIDÆ |
| 9. " DIPRIONIDÆ (PERREYIDÆ, PTERYGOPHORIDÆ, LOBOCERATIDÆ, LOPHRYIDÆ) | |

¹ Also designated as the SYMPHYTA Gehrstecker 1867, PHYTOPHAGA Latreille 1807, or SESSILIVENTRES Haliday 1840. According to Comstock, *Symphyla* is the preferred name (*Symphyla*, from Greek *σύν*, with, + *φυτόν*, a plant or a tree; in reference to their association with plants).

KEY TO IMPORTANT FAMILIES

(Rearranged from MacGillivray, *Hymenoptera of Connecticut*, 1917)

1. Fore wings with free part of R_2 (second interradius) present; antennæ always with more than three segments, third segment usually longer than all the following segments together **XYELIDÆ**
Fore wings with free part of R_2 (second interradius) always wanting; antennæ with three or more segments, third segment never so long as all the following segments together; if third segment be long, antennæ consist of only three segments 2
2. Fore wings with base of subcosta always present; pronotum transverse and scarcely emarginate behind **PAMPHILIIDÆ**
Fore wings with base of subcosta wanting, at most represented only by a pale indistinct line; subcosta usually represented by the free part of Sc_1 , which appears like a cross vein in cell between costa and $R + M$ (subcostal); pronotum transverse but frequently so deeply emarginate behind that the mesal portion is concealed by the head 3
3. Abdomen with distinct pleural sclerites; bearing the spiracles; antennæ clavate **CIMBICIDÆ**
Abdomen without separate pleural sclerites; antennæ not clavate in North American forms 4
4. Scutellum with a distinct apical plate, the posttergite; posterior coxæ contiguous or nearly so; antennæ with more than three joints **TENTHREDINIDÆ** p. 630
Scutellum without a posttergite; posterior coxæ often widely separate; antennæ three-jointed **ARGIDÆ** p. 629

Family XYELIDÆ Haliday 1840 (Xy-el'i-dæ) Xyelid Sawflies.

The members of this small family are distinguished by the very long third antennal segment, the generalized type of wing venation, and the frequently very long ovipositor, while the larvæ are peculiar in having a pair of prolegs on each of the 10 abdominal segments. The larvæ feed on the foliage of deciduous forest trees and shrubs and to some extent also on conifers.

Family PAMPHILIIDÆ Viereck 1916 (Pam'phil-i'i-dæ).

These are called web-spinning and leaf-rolling sawflies and are robust species with primitive wing venation and short ovipositor. The immature forms are entirely devoid of prolegs. The larvæ are often gregarious, and a few species like the plum web-spinning sawfly, *Neurotoma inconspicua* Norton, and the leaf-rolling peach sawfly, *Pamphilius persicus* MacGillivray, are pests in the orchards of eastern North America.

Family CIMBICIDÆ (Leach 1817) Kirby 1837 (Cim-bic'i-dæ, from the Greek *κίμβιξ*, *κίμβυκος*, greedy, avaricious). German, Keulhornblattwespen. Cimbicids, Cimbicid Sawflies.

Large robust dull, brightly colored or metallic sawflies with the antennæ clubbed and always less than eight-segmented; fore tibiae and hind tarsi with

spatulate hairs; pulvilli large; wings with the radial cell divided by a cross vein; female with abdomen globose, tergites divided, and protective scent glands above the spiracles; ovipositor short and barely extending beyond the tip of the abdomen. Larvæ caterpillar-like, large, cylindrical, curled spirally, and usually naked with waxy bloom; thoracic legs large; eight pairs of pseudopods. The larvæ feed upon many kinds of deciduous trees and shrubs and upon small perennials. They hibernate in the soil enclosed within brownish, two-walled, parchment-like cocoons in earthen cells and pupate, the adults emerging in the spring or early summer. The family is a relatively small one and is widely

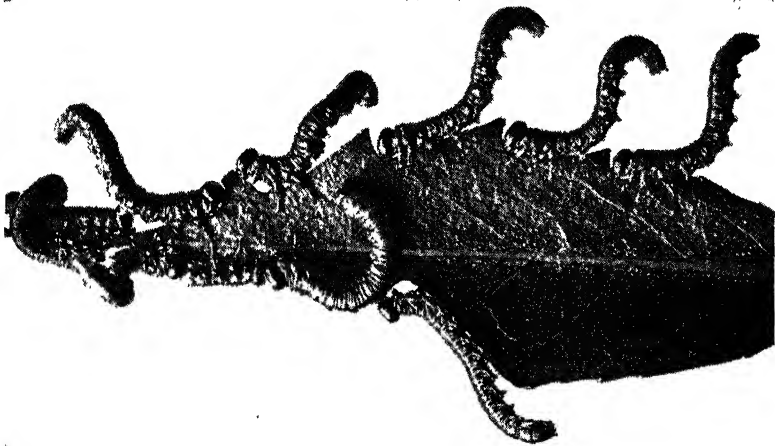


FIG. 214. Sawfly larvæ in natural feeding attitudes on willow leaf. (After Doten from *Insects of Western North America*.)

distributed in the forested temperate regions of the world. The important genera and hosts are:

Abia Leach on honeysuckle, snowberry, strawberry, and other small shrubs. Europe and North America.

Amasis Leach on larkspur. Europe.

Cimbex Olivier on alder, apple, birch, beech, cherry, elm, linden, maple, poplar, willow. Europe and North America.

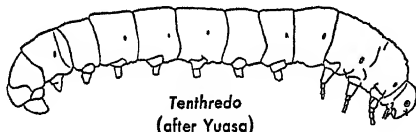
Trichiosoma Leach on birch, hawthorn, mountain ash, willow. Europe and North America.

Family ARGIDÆ Rohwer 1911.

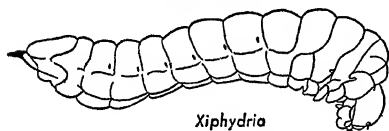
(Ar'gi-dæ) in which the antennæ are three-segmented and the apical segment of the male may be divided or forked. The larvæ feed on broad-leaved deciduous trees and shrubs. Widespread in the north temperate forests.

Family BLASTICOTOMIDÆ Rohwer 1911.

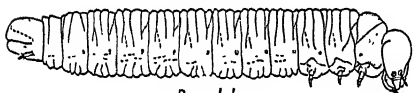
(Blas'ti-co-tom'i-dæ) in which the antennæ are four-segmented with the third very long. The larvæ of *Blasticotoma fliceti* Klug produces a froth-like substance on the leaf petioles of *Asplenium filix-femina* in Europe.



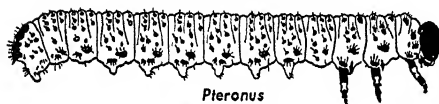
Tenthredo
(after Yuasa)



Xiphydria
(after Yuasa)



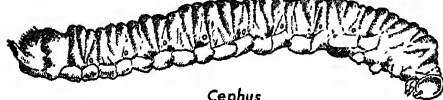
Pamphilus
(after Mac Gillivray)



Pteronus
(after Mac Gillivray)



Caliroa
(after Marlatt, U.S.D.A.)



Cephus
(after Ainsley, U.S.D.A.)

FIG. 215. Larvæ of sawflies and horntails.

Family PERGIDÆ (Ashmead 1900) Rohwer 1911.

(Per'gi-dæ) are Australian sawflies having the radial cells of the fore wings undivided and the abdomen cylindrical. There are two genera, *Perga* Leach with 30 species, the legless larvæ of which feed on eucalyptus leaves, and *Xyloperga* Shipp with 11 species.

Family TENTHREDINIDÆ

Leach 1819 (Ten'thre-din'i-dæ; see superfamily for derivation and meaning). German, Blattwespen. French, Tenthredès or mouches à scie. Sawflies.

Small to medium-sized, stout, wasp-like insects with the broad body closely fused and without an abdominal pedicel. Head wide with many variable structures used in distinguishing the species. Eyes large. Ocelli, three in a triangle on the vertex. Antennæ setiform, three- to six- or eight- to 11-segmented. Legs well developed; fore and hind tibiae usually with single spur; tarsi regularly five-segmented; claws toothed. Wings rather large; with complete venation of the more

primitive type; radial cell entire or divided. Abdomen distinctly eight-segmented; broadly attached to the thorax. Ovipositor consisting of two pairs of flattened plates: the external ones known as the saw guides and the median pair as the saws. Eggs of the flattened type usually inserted in the tissues of the plants or rarely glued to the surface. Larvæ caterpillar-like; cylin-

drical; naked, wrinkled, spiny, or hairy; thoracic legs well developed in most forms, vestigial in a few; from six to eight pairs of prolegs, without crochets, on segments II to VII and X, II to VIII and X, or II to VI and X; all legs reduced or vestigial in gall-producing forms; just a single ocellana on each side; length of mature forms varies from 10–40 mm. Many species are capable of spinning extensive silken webs. All forms are phytophagous and feed externally upon the foliage, mine the leaves, or produce galls in which the larvæ mature.

The exact manner in which the galls of these insects are formed is not clearly understood, but it is generally believed that the larvæ may secrete fluids which

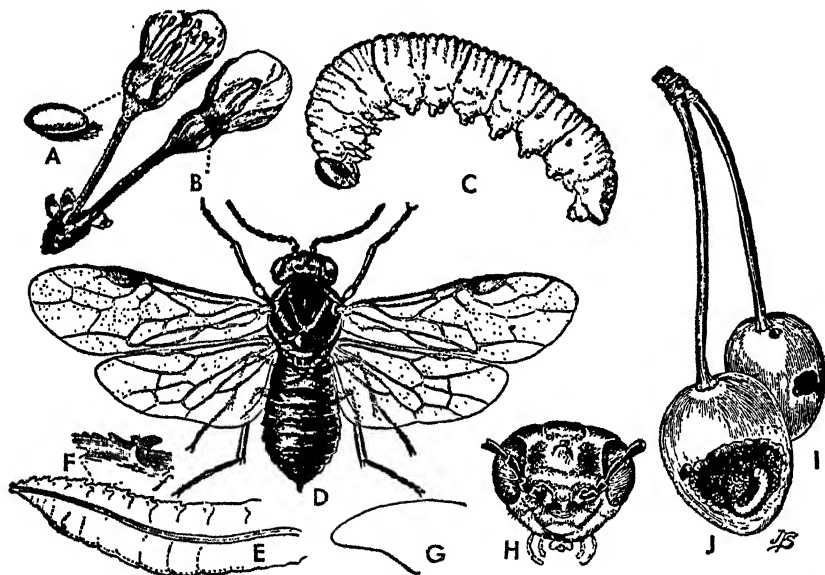


FIG. 216. The cherry fruit sawfly, *Hoplocampa cookei* (Clarke). A, egg; B, position of egg on blossom; C, larva; D, adult female; E and F, ovipositor; G, ovipositor sheath; H, head of adult; I, infested cherries. (After Foster, U.S. Bur. Ent. from *Insects of Western North America*.)

have a definite influence upon the plant cells, thus causing regulated abnormal growth. In the case of the sawfly *Pontania*, the galls are caused by fluids injected into the plant tissues with the egg and the enlargement is made before the larva hatches from the egg. The galls of the European *P. viminalis* (Linn.) which are found on the undersides of willow leaves drop to the ground in fall and winter and continue to increase in size and to develop (Beyerinck, Imms). It would appear that in the latter case the larvæ may have had some stimulating effects on the galls.

Pupation usually occurs in thin parchment-like cocoons in the litter on the surface of the soil or in the soil.

This family is a very large one, consisting of about 200 genera and 3,000

species distributed throughout the world, especially in forested areas. The species are grouped into a number of subfamilies. A list of the commonest subfamilies and genera follows.

<i>Subfamily</i>	<i>Genus</i>	<i>Hosts</i>
EMPHYTINÆ	<i>Empria</i> Lepeletier <i>Emphytus</i> Klug	Strawberries and other small shrubs. Strawberries, roses, and other small shrubs.
SELANDRIINÆ	<i>Selandria</i> Leach <i>Strongylogaster</i> Dahlbom	Ferns. Ferns.
DOLERINÆ	<i>Dolerus</i> Jurine	Grasses, sedges, etc.
PHYLOTOMINÆ	<i>Caliroa</i> O. Costa	Fruit trees and broad-leaved deciduous trees and shrubs.
TENTHREDININÆ	<i>Tenthredo</i> Linn. <i>Macrophya</i> Dahlbom	Broad-leaved deciduous trees and shrubs (elder, viburnum).
HOPLOCAMPINÆ	<i>Hoplocampa</i> Hartig	Pear.
CLADIINÆ	<i>Cladius</i> Illiger	Roses.
NEMATINÆ	<i>Nematus</i> Jurine <i>Diphadnus</i> Hartig <i>Pristiphora</i> Latr. <i>Pachynematus</i> Konow <i>Amauronematus</i> Konow <i>Pteronidea</i> Rohwer <i>Pontania</i> Costa <i>Euura</i> Newman	Birch, oak. Gooseberry, pear. Larch. Grasses, sedges, rumex, spruce, wheat, willows. Azalea, alder, poplar, willows. Birch, alder, currants, gooseberries, locust, oaks, hazelnut, ironwood, poplars, shadbush, willows. Oval or globular greenish, yellowish, and reddish leaf galls on willows and poplars. Swollen stem galls or witches' broom on willows.
BLENNOCAMPINÆ	<i>Isodactium</i> Ashmead <i>Periclista</i> Konow <i>Monophadnus</i> Hartig <i>Monophadnoides</i> Ashmead <i>Blennocampa</i> Hartig	Hickory, oaks. Chionanthus, oaks. Linden. Raspberry. Spiræa.
SCOLIONEURINÆ	<i>Metallus</i> Forbes	Leaf miners on blackberry, dewberry.
FENUSINÆ	<i>Fenusa</i> Leach	Leaf miners on alder.
HYLOTOMINÆ	<i>Hylotoma</i> Latreille	Birch, cherry, honeysuckle, pear, poison ivy, shadbush, strawberry, willows.

Special attention should be called to several species of sawflies. The best known and one of the most important is the cherry or pear slug, *Caliroa*¹ *limacina* Retzius, an Old World species occurring throughout the region from Europe to Japan and introduced into North America, New Zealand, Australia, Tasmania, South Africa, and wherever the hosts are extensively cultivated. The larch sawfly, *Pristiphora erichsoni* (Hartig) (*Lygæonematus*), a species common to the larch forests of Europe and northern North America, is often a very serious pest to forest trees. The European spruce sawfly, *P. polytomus* (Hartig) (*Lygæonematus*), when introduced into Canada proved to be so devastating that large sums have been spent to control it by introducing millions of parasites from Europe as well as those available in North America.

Family DIPRIONIDÆ Rohwer 1911 (Dip'ri-on'i-dæ).

The members have many-segmented and often pectinate antennæ, 32-segmented in the males (segments V to VI serrate) and 23-segmented and serrated beneath in the females; radial cell of fore wings undivided. The larvæ are more or less gregarious and feed on the needles of coniferous trees, chiefly pines. The important genera are *Diprion* Schrank 1802 (= *Lophyrus* Latreille 1802) on pines in Europe and North America and *Monoctenus* Dahlbom on Juniper in Europe.

II. Superfamily SIRICOIDEA

(Si'ri-coi'de-a, origin uncertain, possibly from the Greek *σερικός* or the Latin *sericus* or *siricus*, all meaning silken. Derived from Seres, a people of eastern Asia, the modern Chinese, celebrated for their silken fabrics.)²

10. Family CEPHIDÆ

12. Family SIRICIDÆ

11. " XIPHYDRIDÆ

KEY TO FAMILIES

1. Posterior margin of the pronotum deeply incurved; abdomen more or less cylindrical 2
 Posterior margin of pronotum only slightly curved or straight; abdomen somewhat compressed laterally. (Stern Sawflies.) CEPHIDÆ p. 634
2. Parapsidal furrows of mesonotum present; fore wings with cross vein Sc₁ in the costal cell; abdomen without horn-like prolongation; maxillary palpi four-segmented. (Xiphydriids.) XIPHYDRIDÆ p. 634
 Parapsidal furrows of mesonotum absent; cross vein in subcostal cell absent; abdomen with a horn-like process; maxillary palpi one-segmented. (Horntails.) SIRICIDÆ p. 635

¹ The genus *Caliroa* was erected by O. G. Costa in 1859 and holds priority over *Eriocampoides* which was described by Konow in 1890.

² Other suggested derivations are (1) from the Latin *siricum*, a pigment of ruddy (red) color; (2) from the Greek *Σειρήν*, Siren; a kind of solitary bee or wasp.

Family **CEPHIDÆ** Haliday 1840 (Ceph'i-dæ, from the Greek *κηφήν*, a drone bee). German, Helmwespen. Stem Sawflies.

Slender, fragile, wasp-like insects scarcely more than 18 mm. long and frequently black with yellow bands and other markings. Head large with conspicu-

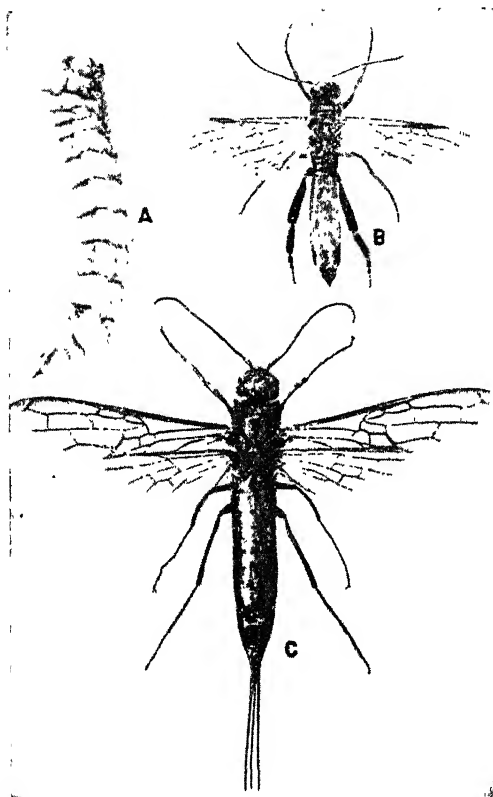


FIG. 217. The western horntail, *Strex areolatus* (Cresson). A, larva; B, male; C, female. (From *Insects of Western North America*.)

ous eyes. Antennæ filiform with many segments. Pronotum long, the posterior margin straight or nearly so. Legs long and slender; tibial spurs well developed. Abdomen somewhat compressed laterally and enlarging apically; ovipositor short and retractile. Eggs oval or pointed; inserted into living plant tissues, chiefly grasses, but also into shrubs and trees. Larvæ pale, C-shaped, wrinkled, apodous or with reduced thoracic legs and vestigial ocelli; with small terminal abdominal appendage or anal spine. Pupæ free, enclosed in thin transparent cocoons in the burrows of the larvæ.

The members of this rather small family are widely distributed throughout the world and occur in grasslands, forests, and cultivated areas. Among the important genera and their hosts are: *Cephus* Latr. on grasses and cereals. The wheat stem sawfly, *C. pygmaeus* (Linn.),

is an Old World pest of wheat and rye which was introduced into North America and has been very destructive in some places. *Hartigia* Schiödt on *Rubus* and other woody plants in Europe and North America. *Janus* Stephens on currants, oaks, poplars, pears in Europe and North America.

Members of the small and related family XIPHYDRIIDÆ¹ (Leach 1817, 1819) Stephens 1829 are characterized by having the antennæ inserted above the eyes; prothorax conical and pronotum reduced to a slender collar forming a

¹ From the Greek *ξιφῶδριον*, diminutive of *ξίφος*, a sword; referring to the ovipositor.

long neck; costal cell of the fore wings divided; and abdomen cylindrical. The genus *Xiphydria* Latr. is represented in Europe by three species the larvæ of which bore into such deciduous trees as alders, birches, elms, oaks, and poplars; in North America by at least six species some of which have been reared from birches and maple; in Australia by a single species, and in New Zealand also by a single species. *Konowia* Brauns has two North American species.

Family SIRICIDÆ Kirby 1837 (Si-ric'i-dæ; see explanation under superfamily).

German, Holzwespen. French, Sirèces. Woodwasps, Horntails.

Large somber or brilliant and metallic wasp-like insects with long closely fused cylindrical bodies terminated by a stout spine and a long stiff ovipositor in the females, which characters are responsible for the common name "horn, tails." Head large and wide but with a very slender neck. Antennæ filiform-many-segmented, nearly half as long as the body. Wings long and narrow with many veins and cells and often partially stained or clouded. Abdomen long, cylindrical, and with anal spine and a short or long, blunt ovipositor consisting of two pieces enclosed in a sheath. The eggs are inserted under or in the crevices of the bark or into the wood of forest trees and shrubs. Once the ovipositor is inserted, it is not quickly removed and such females are easily captured. The pale, cylindrical, S-shaped larvæ are deeply segmented and may also have many annulets and furrows; head large; thoracic legs present and much reduced; terminal horny abdominal process present. They make large burrows in the sapwood and heartwood of conifers and broad-leaved deciduous trees that are injured or have been recently killed. Pupation occurs in thin parchment-like cocoons within the burrows of the larvæ. The species are restricted to forests and are at times fairly abundant.

The members of this family are chiefly Holarctic and are represented in New Zealand by a single species introduced from North America, *Sirex juvencus* (Linn.), which is a pest of felled and old timbers. The most important genera are *Sirex* Linn., *Tremex* Jurine, *Urocerus* Geoffroy, and *Xeris* Costa. *Sirex* attacks conifers. *S. gigas* Linn., 12-40 mm. long, occurs throughout all Europe whereas *S. juvencus* (Linn.) is probably the most widely distributed of the many North American species. *Tremex* infests broad-leaved deciduous trees. *T. magus* (Fab.), 15-40 mm. long, is the important European representative and *T. columba* (Linn.) is North American. *Urocerus* and *Xeris* live in conifers, the former Nearctic and the latter Holarctic.

III. Superfamily ORUSSOIDEA Rohwer 1911

(O'russ-oi'de-a, from the Greek *ὀρύσσω*, to dig, to dig through; referring to their supposed habits as wood borers.)

13. Family ORUSSIDÆ¹ Haliday 1840 (O'russ'i-dæ, see derivation above).

Parasitic Woodwasps.

Small, cylindrical, dull-colored wasps from 8-14 mm. long and with some of the abdominal segments reddish. Head with vertex tuberculate. Antennæ of

¹ The genus from which the family name is derived was originally spelled *Orussus* by

females 10-segmented, of males 11-segmented; inserted below the eyes. Fore tibiae thick and with stout spur in the female. Wings with reduced venation; fore pair with only one closed cubital cell and one recurrent vein. Abdomen with ventral channel on VIII to receive the ovipositor which coils internally; segments IX and X fused into small triangular plates. Eggs of known species with long tube twice the length of the egg; deposited in the cracks or crevices of the bark or within the burrows of the hosts. Larvæ pale, cylindrical, apodous; antennae one-segmented; ocelli absent; mandibles strong; labrum, labium, and maxillae vestigial; parasitic on the larvæ of cerambycid and buprestid beetles. Pupæ with long exposed ovipositor held over the back.

This is a small family composed of very few genera, species, and individuals, but is widely distributed in forested areas. The two most important genera are *Orussus* Latr. in Europe and North America and *Ophrynops* Konow in Australia, New Zealand, and South America.

B. Suborder CLISTOGASTRA Konow 1905

(Clis'to-gas'tra, from the Greek κλειστός, something that can be closed, + γαστήρ, the belly; referring to the nearly closed petiolate abdomen.) (APOCRITA Handlirsch 1906, PETIO-LATA Bingham 1897).

Characterized by having the propodeum or first abdominal segment fused with the metathorax; the second segment constricted or specialized into a slender petiole or pedicel; larvæ apodous.

KEY TO SUPERFAMILIES ¹

1. First abdominal segment ² (and sometimes also segment II) forming a distinct scale, nodule, or petiole, entirely different from the remaining abdominal segments. (Ants.) **FORMICOIDEA** p. 667
 Basal abdominal segments not strongly constricted or petiolate 2
2. Mesothorax with a prepectus (a separate anterior sclerite of the mesepisternum); venation greatly reduced; adults minute, averaging 2-3 mm. in length and with metallic colors **CHALCIDOIDEA** p. 649
 Mesothorax without a prepectus 3
3. Tegulae (small sclerites anterior to the base of each fore wing) present; wings usually well developed, rarely vestigial or absent 4
 Tegulae absent, wingless members present with winged individuals 8
4. Pronotum with sides extending in a line with or to the tegulae 5
 Pronotum with sides remote from the tegulae. 11

Latreille in 1796 but was subsequently changed to *Orussus* by Fabricius in 1798. The original spelling has precedence.

¹J. H. Comstock adds the superfamily EVANIOIDEA and omits FORMICOIDEA, APOIDEA, and CHRYSIDOIDEA as given in this table.

²In all the HYMENOPTERA, the segment which is morphologically the first abdominal segment (propodeum) is intimately fused with the thorax, of which it seems to be a part. In this work the general usage of descriptive writers is followed, and the segment which is apparently the first abdominal segment, though morphologically the second, is uniformly called the first abdominal segment.

A very large family of parasitic wasps which prey mostly upon the immature stages of many orders of insects and parasitize those chiefly of the COLEOPTERA, LEPIDOPTERA, HYMENOPTERA, and DIPTERA. The members are mostly slender species with divided trochanters, and the female normally has a long exerted ovipositor that issues ventrally some distance before the tip of the abdomen.

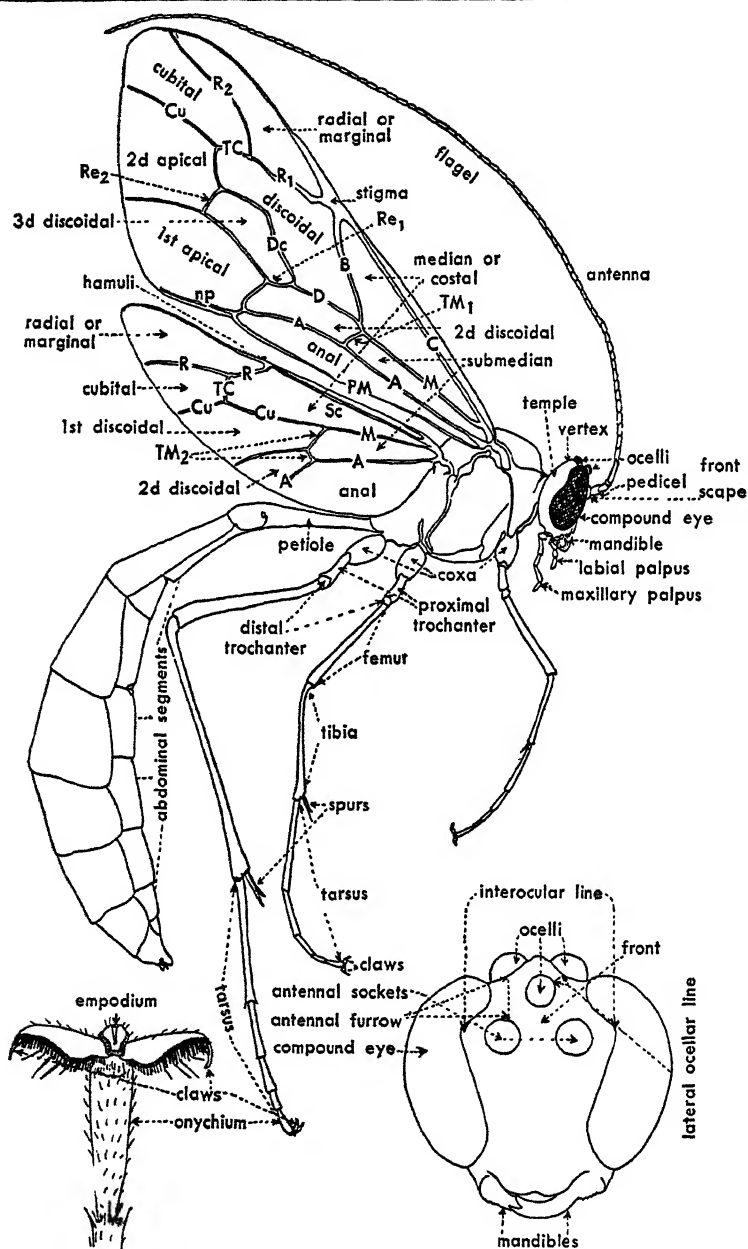


FIG. 218. The ichneumonid fly, *Eremotylus macrurus* (Linn.), and important anatomical parts indicated. (From *Insects of Western North America*.)

LIST OF FAMILIES

- | | |
|-----------------------|------------------------|
| 14. Family MEGALYRIDÆ | 26. Family TRIGONALIDÆ |
| 15. " PAXYLOMMIDÆ | 27. " MONOMACHIDÆ |
| 16. " EVANIIDÆ | 28. " AGRIOTYPIDÆ |
| 17. " BANCHIDÆ | 29. " EUPACHYLOMMIDÆ |
| 18. " CAPITONIIDÆ | 30. " LYSIOGNATHIDÆ |
| 19. " ICHNEUMONIDÆ | 31. " INCUBIDÆ |
| 20. " OPHIONELLIDÆ | (APHIDIIDÆ) |
| 21. " BRACONIDÆ | 32. " LEPTOFOENIDÆ |
| 22. " MYERSIIDÆ | 33. " DINASPIDÆ |
| 23. " ALYSIIDÆ | 34. " VIPIONIDÆ |
| 24. " ALUCIDÆ | 35. " STEPHANIDÆ |
| 25. " GASTERUPTIONIDÆ | 36. " ROPRONIIDÆ |
| (GASTERUPIIDÆ) | |

KEY TO IMPORTANT FAMILIES

1. Costal cell of the fore wings eliminated by the coalescence of the costal and subcostal veins (except in the case of a few rare genera); venter membranous and has a longitudinal fold in dried specimens . . . 2
 Costal cell of the fore wings present; venter sclerotized . . . 4
2. Transverse part of vein M_2 (second recurrent) of the fore wings absent, resulting in the union of cells M and first M_2 . . . 3
 Transverse part of vein M_2 separating cells M and first M_2 . (Ichneumon Flies.) . . . **ICHNEUMONIDÆ** p. 640
3. Abdomen very long and slender and strongly compressed laterally, genus *Pharsalia*. (Ichneumon Flies.) . . . **ICHNEUMONIDÆ** p. 640
 Abdomen not very long and slender and not strongly compressed laterally. (Braconid Flies.) . . . **BRACONIDÆ** p. 643
4. Abdomen attached to the dorsum of the propodeum far above the middle coxæ . . . 5
 Abdomen attached to the propodeum between the hind coxæ or at the end of the propodeum slightly above them . . . 7
5. Transverse part of vein M_2 and at least two closed submarginal cells present in the fore wings (Alucid Wasps.) . . . **ALUCIDÆ** p. 640
 Transverse part of vein M_2 absent in fore wings which also lack two close submarginal cells . . . 6
6. Prothorax long forming a neck; abdomen greatly elongated and clavate; fore wing with radial cell long and pointed. (Gasteruptionid Wasps.) . . . **GASTERUPTIONIDÆ** p. 640
 Prothorax short; abdomen short, upcurved, with slender pedicel; fore wing with radial cell short and broad, or absent. (Ensign Flies.) .
EVANIIDÆ p. 640
7. Fore wings with two or three closed submarginal cells . **TRIGONALIDÆ**
 Fore wings with one closed submarginal cell. (Stephanid Wasps.) .
STEPHANIDÆ p. 646

Family EVANIIDÆ (Leach 1812) Westwood 1840 (Evan-i'i-dæ, from the Latin *evanidus*, frail, feeble; because of their slow movements). Ensign Flies.

Short, robust, somber insects from 4-17 mm. in length, which carry the abdomen raised into the air like an ensign from which habit the common name is derived. Antennae 13- to 14-segmented. Wings with primitive venation, i.e., many cells and broad veins; fore wings with distinct costal cell; with or without one discoidal cell; and radial cell short and broad or absent. Abdomen with long slender pedicel attached high on the upper part of the median dorsal plate above the hind coxæ; gaster small. The larvæ are parasitic and have been reared from eggs of cockroaches and mantids and from the larvæ of xiphydrid horn-tails. The family consists of about 200 species widely distributed and especially well represented in Australia. The important genera are *Brachygaster* Leach, *Evania* Fab., *Hyptia* Illiger, *Hyptiogaster* Kieffer, *Semæodogaster* Bradley.

The members of the related families GASTERUPTIONIDÆ (Ashmead 1900) Handlirsch 1925, parasitic on the larvæ of bees and wasps, and AULACIDÆ Schuckard 1841, parasitic on the larvæ of cerambycid beetles, have the abdomen similarly attached to the propodeum.

Family ICHNEUMONIDÆ Leach 1817 (Ich'neu-mon'i-dæ, from the Greek *ιχνευμων*, a small wasp that hunts spiders; described by Aristotle and Pliny; literally a tracker). German, Schlupfwespen. French, Ichneumonidés. Ichneumonids, Ichneumon Flies.

Minute to large slender parasitic wasps with long, many-segmented, filiform antennæ; three ocelli; well-developed mouth parts; long slender legs with divided trochanters; conspicuous tibial spurs, strong claws, and with an empodium. Wings usually large; rarely absent or brachypterous in both sexes; well-defined venation; costal cells of fore wings eliminated by coalescence of costal and subcostal veins in most forms; median or costal cell separated from discoidal by the veinlet *m-cu*. Propodeum enlarged and prolonged behind the posterior coxæ; often sculptured. Abdomen long and slender; cylindrical or compressed laterally; attached to lower part of propodeum; two or three times as long as the head and thorax; ovipositor variable in length up to six times the length of the body. Eggs either deposited on the outside or inserted within the body of the host; sometimes with a stalk or tube.

Larvæ, especially the endoparasitic forms, undergo a complex metamorphosis with four or five different stages. First stage often with long respiratory prolongation or tail which is reabsorbed; spiracular respiration appears along with the large head in the third stage. The fully developed body is 13-segmented. The larvæ are attached to the exterior walls (ectoparasitic) or may hatch within or bore into the body where they live in the body cavity of the host (endoparasitic). The larvæ may enter either the larval or pupal stages of the host, and the adult ichneumonids usually emerge from the chrysalis or pupa of the host. The most important hosts consist chiefly of the larvæ and pupæ of LEPIDOPTERA, HYMENOPTERA, COLEOPTERA, and DIPTERA in the order named.

The extensive parasitism of the moths and butterflies places these insects among the most important checks to many very serious enemies of agriculture and forestry. The family is a very large one, consisting of some 10,000 species distributed throughout the world wherever the hosts occur. They are most abundant in forested areas but are to be encountered in fields, parks, pasturelands, and orchards. Adults vary in size from the minute apterous *Pecomachus philpotti* Brues of New Zealand, 2 mm. long, to the large North American *Megarhyssa nortoni* (Cresson) which, with the ovipositor, may attain a length of 114 mm. The adults frequently visit flowers, especially the UMBELLIFERÆ, and a few (*Ophion*) are attracted to lights at night.

From so large a group it is extremely difficult to select even a representative list of the most important genera, but those that are generally considered to be most effective and beneficial are here arranged alphabetically with their hosts.

Genus	Length of Adult	Role as Parasite	Important Hosts
<i>Ænoplax</i> Förster	5-8 mm.	Secondary and primary	Parasitic HYMENOPTERA
<i>Amblyteles</i> Wesmæel	8-12 mm.	Primary	LEPIDOPTERA
<i>Angitia</i> Holmgren	4-5 mm.	"	MICROLEPIDOPTERA
<i>Bathyplectes</i> Förster	5-7 mm.	"	RHYNCHOPHORA (<i>Hypera</i>)
<i>Campoplex</i> Gravenhorst	5-7 mm.	"	MICROLEPIDOPTERA
<i>Cremastus</i> Gravenhorst	6-8 mm.	"	"
<i>Diplazon</i> Nees	5-8 mm.	"	DIPTERA (SYRPHIDÆ)
<i>Eremotylus</i> Förster	10-30 mm.	"	MACROLEPIDOPTERA
<i>Ephialtes</i> Gravenhorst	5-16 mm.	"	"
<i>Epiurus</i> Förster	4-8 mm.	"	HYMENOPTERA (TENTHREDINIDÆ), LEPIDOPTERA
<i>Hemiteles</i> Gravenhorst	6-8 mm.	Secondary and primary	LEPIDOPTERA, HYMENOPTERA, COLEOPTERA, DIPTERA
<i>Ichneumon</i> Linnaeus	20-28 mm.	Primary	COLEOPTERA
<i>Itopectis</i> Förster	5-14 mm.	"	MACROLEPIDOPTERA
<i>Megarhyssa</i> Ashmead	75-114 mm.	"	HYMENOPTERA (SIRICIDÆ)
<i>Ophion</i> Fabricius	10-22 mm.	"	MACROLEPIDOPTERA (NOCTUIDÆ), COLEOPTERA (SCARABEOIDEA)

Genus	Length of Adult	Role as Parasite	Important Hosts
<i>Rhyssa</i> Gravenhorst	60-75 mm.	"	HYMENOPTERA (SI- RICIDÆ)
<i>Syrphoctonus</i> Förster	4-8 mm.	"	DIPTERA (SYPRIDÆ)
<i>Thalessa</i> Holmgren	75-100 mm.	"	HYMENOPTERA (SI- RICIDÆ)
<i>Xorides</i> Gravenhorst	12-23 mm.	"	COLEOPTERA (BU- PRESTIDÆ)

Family BRACONIDÆ Kirby 1837 (Bra-con'i-dæ, from the Greek *βραχύς*, short, small, little). Braconids, Braconid Flies.

A family of minute to small parasitic species from 2-12 mm. long; some females with the ovipositor nearly as long as the body. Eyes naked. Ocelli, three present. Hind femora simple or thickened, unarmed or toothed. Wings slender; with two or three submarginal, two cubital, and one discoidal cell; venation sometimes reduced; wings often pictured. Abdomen sessile, subsessile, or petiolate; inserted above or below the hind coxæ; cylindrical or oval; segments I to VIII or III to VIII visible. Larvæ similar to those of preceding family in general form and habits. Adults frequent flowers of goldenrod and other plants. Some of the important genera are characterized as follows:

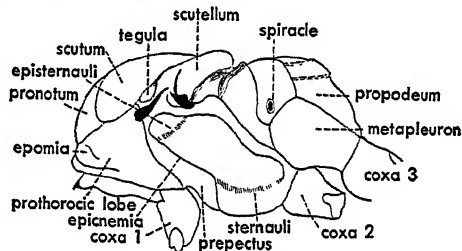


FIG. 220 Thorax of the ichneumon fly, *Thorion morio* (Fab.). (After Viereck, *Hymenoptera of Connecticut*, 1916.)

Genus	Length of Body	Role as Parasite	Hosts
<i>Aleiodes</i> Wesmæl	3.8-8.0 mm.	Primary	LEPIDOPTERA HYMENOPTERA
<i>Ascogaster</i> Wesmæl	3.5-4.5 mm.	"	LEPIDOPTERA
<i>Bracon</i> Panzer	2.0-9.0 mm.	"	LEPIDOPTERA HYMENOPTERA
<i>Bassus</i> Fab.	3.5-6.0 mm.	"	LEPIDOPTERA
<i>Chelonus</i> Jurine	2.5-7.0 mm.	"	"
<i>Dinocampus</i> Förster	3.0-3.5 mm.	"	COLEOPTERA (COCCINELLIDÆ)
<i>Euphorus</i> Nees	3-4 mm.	"	"
<i>Macrocentrus</i> Curtis	5-8 mm.	"	LEPIDOPTERA
<i>Meleorus</i> Haliday	4-6 mm.	"	"
<i>Microgaster</i> Latr.	2.5-4.0 mm.	"	"

Family **INCUBIDÆ** (In-cub'i-dæ, from the Latin *incubus*, a nightmare or evil spirit; because of their parasitic habits). Aphid Parasites.

A small group of minute, slender, active, ant-like parasites of aphids formerly included in the family **BRACONIDÆ** but subsequently placed in a separate

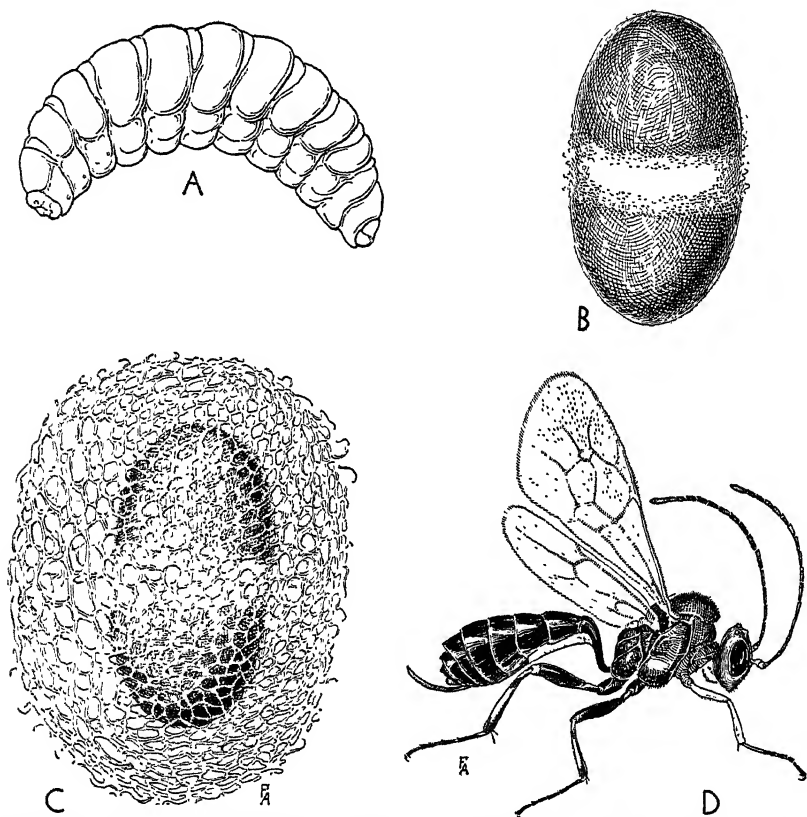


FIG. 221. *Bathyplectes curculionis* (Thomson), the parasite of the alfalfa weevil. A, larva; B, pupa; C, pupa within cocoon of the weevil; D, adult female. (After Michelbacher, 1940.)

family **APHIDIIDÆ** which is now considered to be a synonym of the title above. Antennæ 11-15- or 17-22-segmented. Wings narrow; veins reduced; discoidal cell coalesced with cubital or three cubital cells present; two cubital veins present or absent. The adults vary from 1.5-2.5 mm. in length. The eggs are inserted directly into the bodies of the aphids by the active females. The larvæ are small, C-shaped, and apodous. A single specimen occupies to maturity the body of the host, within which it feeds and pupates, and from which it finally emerges through a circular hole cut in the dorsum by the mandibles of the adult. In certain species the larvæ and pupæ hibernate in the dead

carcasses of the hosts which are attached to the plant by slitting the venter and gluing the aphids to their original support. Members of the genus *Praon* construct a remarkable cocoon beneath the body of the host, upon which the former rest. The lighter colored mummied bodies of the parasitized aphids are often very conspicuous among colonies of these common insects, and parasitism often takes a toll of from 50 to 95 or rarely even 100 per cent of a colony. While the parasites are common and abundant wherever aphids occur, they appear to have little effect upon the prevalence of the hosts. The species are limited practically to the temperate regions.

Among the important genera are *Blacus* Nees, *Ephedrus* Haliday, *Incubus* Schrank (= *Aphidius* Latr., *Diaretus* Bonvouloir, *Lysiphlebus* Förster and *Trioxys* Haliday), *Monoclonus* Haliday, *Praon* Haliday, and *Toxares* Haliday.

Family VIPIONIDÆ Viereck 1918 (Vi'pi-on'i-dæ, from the Latin *vipio*, a kind of small crane; referring to the long legs of these parasitic wasps). Vipionids.

Tiny to small slender parasites distinguished by the 14- to 18-segmented antennæ; entire or emarginate clypeus; undivided mesothorax; long- or short-spurred hind tibie; wings with two small and imperfect second submarginal cells that may be absent, and a third submarinal that may extend nearly to apex of the wings. The adults insert large numbers of eggs into the bodies of the hosts, the dead carcasses of which may be wholly covered by the multitudinous white or yellow cocoons spun by the larvæ of the parasite and from which the adults subsequently emerge. The hosts consist chiefly of the larvæ of LEPIDOPTERA, HYMENOPTERA, COLEOPTERA, and DIPTERA. The family is a relatively small one separated from the BRACONIDÆ and is widely distributed, the important genera being cosmopolitan in distribution. Certain species are often very abundant and are effective parasites on many destructive caterpillars, beetle larvæ, and others of the hosts listed above. A list of the outstanding genera follows:

Genus	Length of Adult	Role as Parasite	Important Hosts
* <i>Apanteles</i> Förster	1.65-3.00 mm.	Primary	LEPIDOPTERA
<i>Cæloides</i> Wesmæl	2.6-5.6 mm.	"	COLEOPTERA (RHYNCHOPHORA)
<i>Habrobracon</i> Ashmead	2-3 mm.	"	LEPIDOPTERA
<i>Microbracon</i> Ashmead	2-4 mm.	"	LEPIDOPTERA COLEOPTERA
<i>Habrobraconidea</i> Vier.	3.5-.5 mm.	"	<i>Pissodes</i>
<i>Microplitis</i> Förster	2.2-6.00 mm.	"	LEPIDOPTERA
<i>Opius</i> Wesmæl	1.25-3.00 mm.	"	DIPTERA (Several families)

* *Apanteles glomeratus* (Linn.), the European parasite of the cabbage butterfly, *Pieris rapæ*

Family STEPHANIDÆ (Leach 1815) Haliday 1840 (Steph-an'i-dæ, from the Greek *στέφανος*, a crown or garland; in reference to the tubercles on the head). Stephanid Wasps.

Very peculiar, slender species in which the males are much smaller than the females and the latter may have an ovipositor longer than the body. Head globose and tuberculate above. Antennæ filiform, 30- to 70-segmented; attached near clypeus. Mesothorax undivided. Wings narrow; venation somewhat reduced; costal cell distinct; hind wings with or without closed cells. Hind femora enlarged and may be toothed ventrally; hind tarsi of female three-

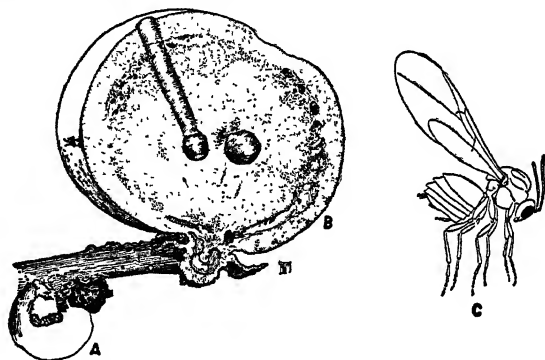


FIG. 222. The California gallfly, *Andricus californicus* (Bassett). A, small immature gall; B, cross-section of mature gall or "oak apple" showing texture, cells of the gallfly, and exit holes of the adults; C, adult female. (From *Insects of Western North America*.)

five-segmented. Abdomen long and slender, somewhat dilated posteriorly; attached close to the hind coxæ by a long pedicel. Little is known about the immature stages and the biology of these remarkable insects. Species of the cosmopolitan genus *Stephanus* Jurine are known to be parasitic on wood-boring insects. The Queensland *S. crassicauda* Morley, probably the largest known species, measures: antennæ 14 mm., body 36 mm., ovipositor 40 mm. There are about 10 genera and 100 described species.

V. Superfamily CYNIPOIDEA Ashmead 1899

(Cyn'i-poi'de-a from the Greek *κνίψ*, *κνιπός*, a small insect that gnaws figs). French, Cynipides. German, Gallwespen. Gallwasps, Gallflies, Fig Wasps.

Minute to small insects, mostly 1-4 mm. (7-16 mm. in IBALIIDÆ); robust or slender; usually shining or somewhat pubescent; black, dark maroon, bluish and shining, or varying from brown to yellow; characterized chiefly by simple antennæ; the pronotum extends to the tegulæ; the trochanters undivided; (Linn.), was the first natural enemy purposely introduced into the United States by C. V. Riley in 1883 to combat a previously introduced pest, the cabbage butterfly. It has been quite efficient only in certain parts of this country.

greatly reduced venation with at most not more than five closed cells and without stigma in the fore wings and an anal lobe in hind wings; ovipositor retractile and coiled, issuing well before the extremity. The great majority of them produce galls on oak trees, but the small families are parasitic on other insects.

LIST OF FAMILIES

- | | |
|------------------------------|----------------------|
| 37. Family CYNIPIDÆ | 41. Family EUCOILIDÆ |
| 38. " FIGITIDÆ | 42. " ASPICERIDÆ |
| 39. " IBALIIDÆ | 43. " ANACHARITIDÆ |
| 40. " CHARIPIDÆ (ALLOTRIIDÆ) | |

KEY TO FAMILIES

(Modified from H. Hedicke, 1930)

1. Segment II of the hind tarsi with an outer styliform process; cubitus vein arising between the middle and the base of the subcostal; abdomen much compressed laterally; 7-16 mm. long. (Parasitic on wood wasps.) **IBALIIDÆ**

Segment II of the hind tarsi without outer process; cubitus vein arising near the middle of the subcostal or lacking; abdomen globular or compressed laterally; usually 1-3 mm. long, not exceeding 3 mm. (Gall-making and parasitic species.) 2

2. Scutellum with a cup-shaped, depressed, or rarely only flattened prominence. (Parasitic species.) . . . **EUCOILIDÆ**

Scutellum without such noticeable prominence 3

3. Second tergite narrow, tongue-like, and shorter than the third tergite. (Parasitic species.) **ASPICERIDÆ**

Second tergite neither narrow nor tongue-like and much longer than the third tergite 4

4. Second tergite shorter than half the width of the abdomen; cubitus arising from the base of the subcostal or lacking 5

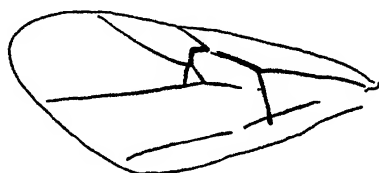
Second tergite at least half the width of the abdomen; if shorter than the cubitus, it arises from the middle of the subcostal vein . . . 6

5. Abdomen distinctly petiolate; second tergite longer than the third. (Parasitic species.) **ANACHARITIDÆ**

Abdomen not distinctly petiolate, rather joined well upon the propodeum; second tergite shorter than the third. (Secondary parasites on aphids and coccids.) **FIGITIDÆ**

6. Thorax distinctly sculptured or, if smooth, then the areolet of fore wing is completely formed; up to 6 mm. in length, rarely less than 2 mm. (Gallwasps, Gallflies.) **CYNIPIDÆ** p. 648

Thorax smooth, flat, and shining, areolet of fore wing absent; at least 2 mm. or longer. (Secondary parasites of aphids.) . . . **CHARIPIDÆ**



Andricus californicus
(Bassett)

FIG. 223. Wing of the California gallfly.

Family CYNIPIDÆ (Haliday 1840) Westwood 1840 (Cy-nip'i-dæ; see derivation *supra*). Gallwasps, Gallflies, Cynipids.

Minute to small, 1–6 mm., black, brown, or paler in color; smooth and shiny or partly pubescent. Head small and sometimes deflexed because of the rounded thorax. Antennæ setiform, 11- to 16-segmented. Pronotum fused with metanotum, sides extending to tegulæ.

Legs slender; trochanters small and undivided; posterior claws simple or bidentate. Wings absent, rudimentary, or fully developed; males may be alate and females apterous or with vestigial wings; with few veins and microtrichia; fore pair with only five closed cells including the small areolet. Scutellum and propodeum often deeply sculptured. Abdomen globular or compressed laterally; with or without a short petiole; tergites well chitinized and not concealing sternites; segment II normal or extending over posterior tergites; ovipositor issuing from near middle of abdomen and coiled within it.

The adults are wasp-like or ant-like in appearance and bisexual or agamic or parthenogenetic, and many have alternate fall agamic generations. They appear in the fall or spring, when the eggs are inserted in the dormant or developing buds, leaves, stems, or roots of the host plants, resulting in the production of a great variety of galls on all



FIG. 224. Spiny galls of *Diplolepis politus* (Ashmead) of the leaves of wild rose. A widely distributed North American gall. (From *Insects of Western North America*.)

parts of the plants including the roots, stems, petioles, leaves, floral parts, or seeds. The galls or swellings begin to develop soon after the larvæ hatch from the eggs, and it is believed that the proliferation is caused by the larvæ. The character of the galls is determined by the insect rather than by the plant, and each species produces one or more characteristic kinds of galls. According to Kinsey, about 86 per cent of all cynipid galls are produced on *Quercus*, 7 per cent on *Rosa*, and 7 per cent on COMPOSITÆ. Many spe-

cies live in the stems and produce no galls, but certain of these may produce a thick, shell-like cyst in which the young develop. The larvæ are minute, pale-colored and apodous, with small head, vestigial antennæ and palpi, dentate mandibles, 12-segmented body, and nine pairs of spiracles.

The family is a large one and its distribution is largely determined by that of its most important host plants, the oaks (*Quercus* spp.), which are most abundant in the north temperate regions and extend into the higher altitudes of the tropics where they may become very numerous. There is a large number of genera of which the most important ones on oak are *Andricus* Hartig, *Callirhytis* Förster, *Cynips* Linn., *Diastrophus* Hartig, *Disholcaspis* Dalla Torre and Kieffer, *Dryophanta* Förster, and *Neuroterus* Hartig; and on *Rosa* spp., *Diplolepis* Geoffroy and *Rhodites* Hartig.

One of the most conspicuous galls is the large oak apple produced by *Andricus californicus* (Basset). These galls are green when developing and later turn almost white when dried. They vary in size from a walnut to an apple. Another interesting gall in California is the tiny bead-like jumping gall of *Neuroterus saltatorius* (Edwards) which is formed in great numbers on the undersides of the leaves of the valley oak. They are but 1-2 mm. in diameter, deciduous, and drop to the ground in late summer and autumn. The active larvæ within throw themselves against the thin walls with such force as to cause the galls to jump several inches. Under a single large tree, thousands of these tiny galls may be seen jumping in all directions. When a crack in the soil or other place of lodgment is found, movement ceases and the larvæ go into hibernation within the gall.

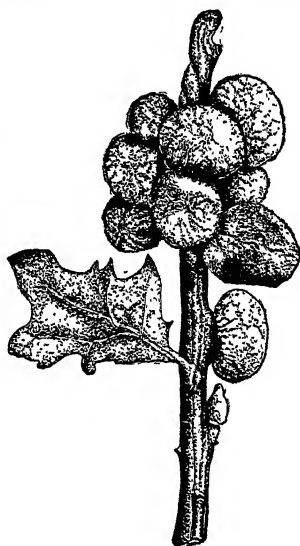


FIG. 225. Honey galls of *Disholcaspis eldoradensis* (Beutenmüller), on an oak twig. This is a remarkable North American gall that, during development, exudes quantities of a sweet nectar eagerly sought by the honeybee. (From *Insects of Western North America*.)

VI. Superfamily CHALCIDOIDEA Ashmead 1897

(Chal'cid-oi'de-a, from the Greek χαλκός, copper; from the metallic copper iridescences.) German, Chalcidier. Chalcid Flies.

A very large group of many thousand species, 0.2-5.0 and a few attaining 16 mm. in length. Head transverse; eyes large; ocelli three in a row or a triangle on or in front of vertex; antennæ mostly elbowed, six- to 13-segmented, scape long, one or more ring joints between pedicel and funicle; some with funicle clubbed. Pronotum small or large, sides not extending to tegula; scutellum well developed. Trochanters small, usually divided into two parts; tarsi three-

to five-segmented; hind femora normal or greatly enlarged. Wings usually present or rarely absent; fore pair sometimes folded in repose; veins greatly reduced and consist of submarginal, marginal, stigmal, and poststigmal — the last two may be absent. Abdomen sessile or petiolate; ovipositor issues before the tip of the abdomen. Mostly parasitic in the various stages of a great many groups of insects and a few phytophagous in galls and seeds.

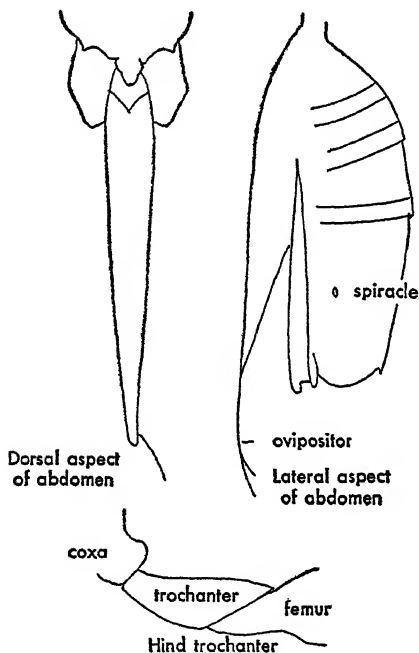
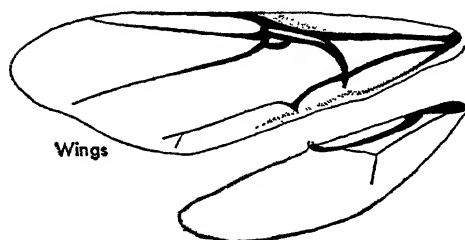


FIG. 226. Wings, abdomen, and basal portion of leg of *Ibatia ensiger* Norton.

LIST OF FAMILIES

- | | | | |
|------------|---|------------|---|
| 44. Family | CHALCIDIDÆ | 57. " | EULOPHIDÆ |
| 45. " | PERILAMPIDÆ | 58. " | TETRASTICHIDÆ |
| 46. Family | EUCHARITIDÆ
(EUCHARIDÆ) | 59. " | APHELINIDÆ |
| 47. " | CALLIMOMIDÆ
(TORYMIDÆ) | 60. " | ELACHERTIDÆ |
| 48. " | AGAONTIDÆ (AGA-
ONIDÆ, BLASTO-
PHAGIDÆ) | 61. " | ENTEDONTIDÆ |
| 49. " | EURYTOMIDÆ | 62. " | ELASMIDÆ |
| 50. " | CLEONYMIDÆ | 63. " | TRICHOGRAMMA-
TIDÆ (TRICHO-
GRAMMIDÆ) |
| 51. " | PTEROMALIDÆ | 67. Family | LEUCOSPIDIDÆ |
| 52. " | SPALANGIIDÆ | 68. " | MICROGASTERIDÆ |
| 53. " | ENCYRTIDÆ | 69. " | TRIDYMIDÆ |
| 54. " | EUELMIDÆ | 70. " | ALIENIDÆ |
| 55. " | SIGNIPHORIDÆ | | |
| 56. " | TANAOSTIGMA-
TIDÆ | | |
| 64. Family | MYMARIDÆ | | |
| 65. " | ORMYRIDÆ | | |
| 66. " | LEPTOFENIDÆ
(PELECINELLIDÆ) | | |

KEY TO IMPORTANT FAMILIES¹

1. Hind wings neither linear nor pedunculate at base; ovipositor issues far in front of tip of abdomen; antennæ elbowed and with one, two, or three ring joints, very rarely without ring joints 2
- Hind wings linear, pedunculate at base; ovipositor usually issues just in front of tip of abdomen; antennæ in female most frequently terminates in a distinct fusiform or egg-shaped solid club, more rarely in a two-segmented club MYMARIDÆ p. 660
2. Tarsi four- or five-segmented; fore tibiæ armed with a large curved spur; antennæ usually many-segmented 3
- Tarsi usually four-segmented, rarely three-segmented; very rarely heteromerous; fore tibiæ with a delicate short straight spur; antennæ usually with few segments, at most nine-segmented 16
3. Hind femora much swollen 5
- Hind femora not greatly enlarged 4
4. Males always apterous; abdomen broadly sessile, long and tubular, thickened at base, or broadened apically with a tubercle or filament at each apical angle. (Fig Wasps.) AGAONTIDÆ p. 654
- Males most often winged, rarely apterous; if apterous, the abdomen is normal and not long and tubular 6
5. Fore wings, when at rest, folded longitudinally; ovipositor curved over dorsum of abdomen LEUCOSPIDIDÆ
- Fore wings not folded; ovipositor not curved over dorsum of abdomen. (Chalcid Flies.) CHALCIDIDÆ p. 652
6. Thorax strongly developed, much arched, and deeply punctate 7
- Thorax not strongly developed 8
7. Stigmal vein not well developed, always short and subsessile; second abdominal segment very large and usually encloses other segments EUCHARITIDÆ
- Stigmal vein developed; all abdominal segments visible. PERILAMPIDÆ p. 653
8. Pronotum large; antennæ many-segmented; notaulices complete 9
- Pronotum small, frequently not visible in the middle; antennæ usually with few segments 10
9. Hind coxæ greatly enlarged; ovipositor not prominent; body not metallic; sides of scutell almost straight EURYTOMIDÆ p. 655
- Hind coxæ normal; ovipositor often exserted; body usually metallic; sides of scutell curved (TORYMIDÆ) CALLIMOMIDÆ p. 653
10. Mesosternal pleuræ not visible; middle legs long, saltatorial, with a very long tibial spur 11
- Mesosternal pleuræ distinct; middle legs not saltatorial, first tarsal segment not swollen 13
11. Antennæ more than six-segmented 12
- Antennæ six-segmented; marginal vein about as long as subcostal vein SIGNIPHORIDÆ p. 657
12. Antennæ usually 13-segmented; occipital margin of vertex rounded EUPELMIDÆ
- Antennæ usually 11-segmented; occipital margin of vertex usually acute; notaulices obliterated ENCYRTIDÆ p. 656

¹ After Viereck, *Hymenoptera of Connecticut*, pp. 444-446, 1916.

13. Antennæ 12- or 13-segmented 14
 Antennæ four- to nine-segmented; notaulices distinct; middle tibial spur moderately long; stigmal vein very short, nearly obsolete, the knob sessile or subsessile; mesopleura without a femoral furrow
APHELINIDÆ p. 658
14. Antennæ usually 12-segmented 15
 Antennæ 13-segmented, with two ring joints and three segments to the club; occipital line incomplete **PTEROMALIDÆ** p. 656
15. Abdomen distinctly petiolate; occipital line complete **SPALANGIDÆ**
 Abdomen almost sessile; pronotum scarcely visible in the middle, submarginal vein subangulate, stigmal club often large, notaulices distinct; funicle of antennæ five-segmented **TRIDYMIDÆ**
16. Tarsi four- or five-segmented 17
 Tarsi three-segmented; pubescence of wings arranged linearly
TRICHOGRAMMATIDÆ p. 660
17. Submarginal vein entire, furnished with many bristles; postmarginal vein distinct; hind tibiæ sometimes with two spurs 18
 Submarginal vein broken; postmarginal vein sometimes wanting; hind tibiæ with one spur; male antennæ simple 20
18. Abdomen sessile or with a distinct petiole that is transverse and smooth; notaulices either absent or represented only by very slight impressions 19
 Abdomen usually with a distinct petiole; notaulices very distinct; antennæ inserted below middle of face, simple in male; mesonotum with parapsidal furrows complete, distinct, entire **ELACHERTIDÆ**
19. Hind coxæ very large and strongly compressed; head semiglobose, front deeply, sparsely punctate; antennæ flabellate in male; marginal vein in fore wings usually extraordinarily lengthened, the radius very short, scarcely dilated; mesonotum without furrows **ELASMIDÆ**
 Hind coxæ normal; tarsi four- to five-segmented, rarely heteromerous; marginal and radial veins normal; postmarginal vein often missing; mesonotum with complete or incomplete furrows; antennæ often flabellate in male; mesonotum with parapsidal furrows incomplete or absent, at most only slightly indicated anteriorly **EULOPHIDÆ** p. 657
20. Submarginal vein very short, either ornate or provided with two bristles; marginal vein very long; postmarginal vein variable, often very short or indistinctly developed; metapleura very small; scutel with two bristles near the middle **ENTEDONTIDÆ**
 Submarginal vein usually longer than the marginal vein with one to five bristles; stigmal vein distinct, never subsessile, usually long; metapleura triangular, not small; mesopleura with a distinct femoral furrow; postmarginal vein usually absent; scutel with four bristles, all behind the middle, often with two longitudinally impressed lines; abdomen sessile **TETRASTICHIDÆ** p. 658

Family CHALCIDIDÆ (Leach 1830) Westwood 1840 (Chal-cid'i-dæ; see derivation under superfamily). German, Zehrwespen. Chalcid Flies, Chalcids.

Minute, 2-7 mm., mostly black or brown, marked with white, yellow or reddish; nonmetallic. Head small. Antennæ simple and short. Eyes large.

Ocelli in a row on the vertex. Thorax greatly enlarged and gives a humped-backed appearance. Legs small; hind femora very greatly enlarged and dentate or serrate ventrally; hind tibiae curved inwardly. Wings ample, not folded longitudinally; veins reduced to the subcosta, part of the postmarginal, and a remnant of the radius.

Abdomen with short petiole; tip may be drawn out into a point; ovipositor arises basad to tip, straight, rarely long. The adults crawl, hop, and fly. They are ecto- and endoparasitic on the larvæ and pupæ of other insects and involve one to four grades of parasitism, but are mostly primary and secondary on the larvæ of COLEOPTERA and LEPIDOPTERA and primary on immature DIP-

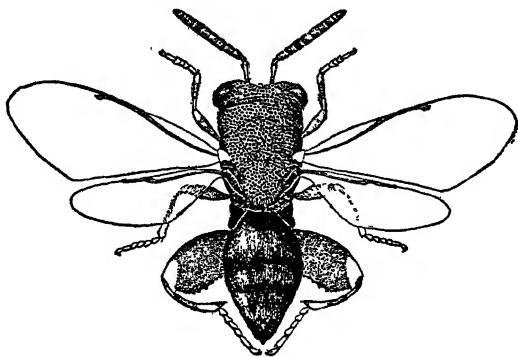


FIG. 227. The black and yellow chalcid, *Brachymeria abiesiae* (Girault), a parasite frequently reared from the pupæ of moths. (After Herbert, U.S.D.A. from *Insects of Western North America*.)

TERA. The most important genera are *Brachymeria* Westwood, *Chalcis* Fab., *Dirhinus* Dalman, *Haltichella* Spinola, *Phasgonophora* Westwood, *Smicra* Spinola, *Spilochalcis* Thomson, and *Trigonura* Sichel.

Family PERILAMPIDÆ Cameron 1884 (Per'i-lamp'i-dæ, from the Greek περιλάμπω, to beam or shine around; referring perhaps to their brilliant metallic colors). Perilampids.

A small family of minute, highly specialized species, the first stages being known as planidium larvæ. These almost microscopic forms assume an upright position on the foliage or other places frequented by the hosts and attach themselves to the hosts when they come within reach. They then become internal primary and secondary parasites. *Perilampus chrysopæ* Crawford, 2 mm., secondary through primary parasites on green and brown lacewings and *P. hyalinus* Say, 5 mm., a secondary through ichneumonids on caterpillars, are two common North American species.

Family CALLIMOMIDÆ¹ Viereck 1916 (Call'i-mom'i-dæ, from the Greek κάλλιμος, beautiful; referring to their iridescent metallic colors). Beautiful Parasites, Callimomids, Seed Chalcids.

Minute, 2-4 mm., parasites and seed-infesting chalcids, with brilliant metallic colors. They comprise a large family. Members of the genus *Megastigmus*

¹ The family name TORYMIDÆ Walker 1833 is used by some writers. The genus *Callimome* was erected by Spinola in 1811 whereas the synonym, *Torymus*, was erected by Dahlbom in 1820. The former genus has priority in the establishment of the family name as given above.

Dalman were formerly believed to be phytophagous, seed-infesting chalcids of conifers, but it is now generally thought that certain species are phytophagous and others are parasitic — the latter also on gallwasps. *Syntomaspis druparum* Boheman infests apple seeds in North America and Europe. By far the greater number of genera and species are parasitic and hyperparasitic on eggs, larvæ, and pupæ of HYMENOPTERA (gallwasps, jointworms, and rarely bees), LEPIDOPTERA, DIPTERA, and the eggs of MANTODEA.

Family AGAONTIDÆ¹ Walker 1846 (Ag'a-on'ti-dæ, from the Greek ἀγῶμαι, to wonder at; because of the remarkable appearance of the male and the complicated life histories of these insects). Fig Wasps.

Minute to small, highly specialized wasps, 2–3 mm. long, inhabiting the fruits of various kinds of figs and normally rearing the young in the seeds. The females are black, winged; head

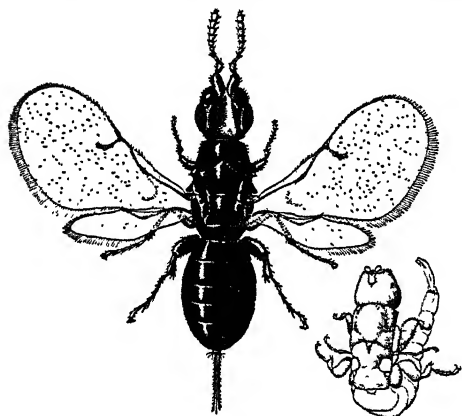


FIG. 228. The adult winged female and apterous male of the fig wasp, *Blastophaga psenes* (Linn.). (After Condit, 1920.)

grooved down the middle or around the antennæ; antennæ 9- to 13-segmented and with long scape; eyes and ocelli present, tarsi usually five-segmented. The males are queer looking, pale-colored; apterous; exceedingly small, blind; with short, three- to nine-segmented antennæ; minute undeveloped middle legs which are absent altogether in some species; fore tibia with large curved spur; tarsi three- to five-segmented.

The females move from tree to tree in search of figs in proper condition for fertilization while

the males remain and perish in the figs in which they were reared. In some forms at least the females, even before they leave the seeds, are fertilized by the curious male which is furnished with strong mandibles for making a hole in the wall of the seed and with a long extensile abdomen, normally carried curled beneath the body, for mating.

The best known life history is that of the important Old World economic species commonly known as the blastophaga, *Blastophaga psenes* (Linn.), which propagates in certain types of inedible Smyrna figs known as caprifigs (*Ficus carica* var. *sylvestris*) which are rich in pollen. Leaving these large-seeded fruits covered with pollen, the female enters the large edible figs (*Ficus carica* var. *smyrnica*) and in attempting to oviposit in the seeds pollinates the latter. Because of their very long styles, however, she is unable actually to insert her

¹ From the Greek stem ἀγῶνν, hence AGAONTIDÆ and not AGAONIDÆ as commonly used (Tillyard 1925, p. 275).

eggs into them. Therefore, without gain to herself, she performs an act no other natural agent is able to consummate, and it is only by her efforts that commercial edible Smyrna figs can be produced.

While many species of figs are pollinated by various members of this family, there are commercial varieties of figs like the Black Mission, Kadota, Magnolia, White Adriatic, and others which do not require the services of these insects in order to produce edible fruits.

Family EURYTOMIDÆ Walker 1833 (Eu'ry-tom'i-dæ, from the Greek *εὐρύς*, wide, broad, spacious, + *τομή*., segment, division, or section; referring to the body divisions). Eurytomid Wasps, Straw Worms, Joint Worms.

Minute to small, 1.5–6.0 mm., mostly black and metallic, rarely yellow. Antennæ of male may be tuberculate or warty and haired on the upper surface;

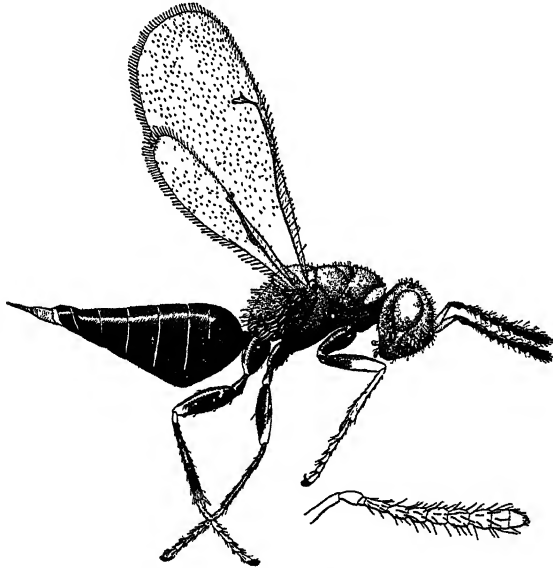


FIG. 229. Wheat sheath wasp, *Harmolita vaginicola* (Doane). (After Doane, from *Insects of Western North America*.)

10- to 13-segmented; funicle of the male four- to five-segmented. Thorax large, punctate; pronotum large and square or rectangular. Fore tibiae with large spur; hind tibiae two-spurred. Fore wings with marginal, postmarginal, and stigmal veins present. Abdomen smooth. Partly sheathed ovipositor issues far in front of the extremity. The members of this family have a variety of habits, some being parasitic and others phytophagous.

The family is a large one and, although widely distributed, is richest in the Holarctic region. Genera containing parasitic species are *Microrileya* Ashmead

on eggs of tree crickets; *Euchrysa* Westwood on larvæ of buprestid beetles; *Decatoma* Spinola, *Eudecatoma* Ashmead, and *Eurytoma* Illiger in the galls of gall wasps, the last named also on eggs of moths; *Axiina* Walker in the nests of small carpenter bees; and *Rileya* Ashm. in galls of gall gnats.

Phytophagous forms include *Eurytoma* Illiger on stems, bulbs, or roots of orchids; *Harmolita* Motschulsky and *Isosoma* Walker on the stems of grasses and cereals; *Bruchophagus* Ashm. and *Decatomidea* Spinola on alfalfa and clover seeds; and *Evoxystoma* Ashm. on grape seeds. The wheat straw worm, *Harmolita grandis* (Riley), and the wheat joint worm, *H. tritici* (Fitch), are serious pests of wheat and of other cereals and grasses, and the clover seed chalcis, *Bruchophagus funebris* Howard, is a serious pest of clover and alfalfa seed in many parts of North America.

Family PTEROMALIDÆ Walker 1833 (Pter'-o-mal'i-dæ, from the Greek πτερά, wings, + ὁμαλός, even, level). Jewel Wasps, Pteromalids.

Minute, 1-2 mm., active, running, jumping, and flying; mostly metallic green, blue, gold, copper, or other iridescent shades. Eyes large; antennæ geniculate. Mandibles with three or four teeth. Thorax large and arched; scutellum may be very large; mesopleura grooved. Legs normal or the fore femora enlarged; fore tibiæ with a stout spur; middle and hind tibiæ each with a single spur; tarsi five-segmented. Wings with small or large stigmata. Ovipositor usually short.

The members of this very large and cosmopolitan family are parasitic and hyperparasitic on practically all orders of insects, and many of them are of great importance as destroyers of insect pests. *Aplastomorpha vandinei* Timberlake is a cosmopolitan parasite of the granary and rice weevils. *Dibrachoides dynastes* (Förster) is a common parasite of the alfalfa weevil in southern Europe and has been introduced into the United States. *Dibrachys boucheanus* (Ratzeburg) is one of the commonest species in Europe and North America, being a primary and secondary parasite on LEPIDOPTERA and HYMENOPTERA. *Merisus destructor* (Say) is a common parasite of the Hessian fly in North America. *Nason brevicornis* Ashmead parasitizes the pupæ of the housefly. *Pteromalus puparum* (Linn.) is a very important parasite of the cabbage butterfly and related species in Europe and also in North America since its introduction. It destroys the chrysalids. *Scutellista cyanea* Motschulsky is a widely distributed parasite of the black scale and the wax scales in many tropical and subtropical regions and in greenhouses elsewhere.

Family ENCYRTIDÆ Walker 1837 (En-cyr'ti-dæ, from the Greek ἐγκυρτος, curved, arched; in reference to the somewhat arched body). Encyrtid Parasites.

Minute, 1-2 mm., smooth or punctured, dark metallic and lustrous parasitic species. Head wide. Antennæ short, eight- to 12-segmented (usually 11-, rarely 6-segmented). Eyes large. Ocelli in triangle. Scutellum and mesopleura large. Fore tarsi with large spur. Middle legs often enlarged for jumping; tibiæ long,

fringed with spines on the inner margin, and with a stout apical spur. Tarsi five-segmented. Wings rarely rudimentary, usually well developed; venation reduced; fore pair with only marginal, stigmal, and poststigmal veins. Ovipositor issues far basad to the tip of the abdomen. The members of this very large and cosmopolitan family are not only ecto- and endoparasitic but primary and hyperparasites as well. They parasitize the egg, larval, and pupal stages of the host. Some genera exhibit polyembryony. Hosts of a few representative genera are as follows:

ARANEIDA (Ticks) — *Hunterellus* Howard.

NEUROPTERA (Chrysopids) — *Isodromus* Howard.

HOMOPTERA — (Aphids) — *Aphidencyrus* Ashmead.

(Fulgorids) — *Fulgoridicida* Perkins.

(Coccids) — *Acerophagus* Smith, *Ænasioides* Girault, *Anagyrus* Haliday, *Anusia* Förster, *Aphycus* Mayr, *Blastothrix* Mayr, *Chalcaspis* Howard, *Cheiloneurus* Westwood, *Chrysoplatycerus* Ashmead, *Cirrhecyrus* Timberlake, *Comys* Förster, *Encyrus* Latr., *Eucomys* Förster, *Eusemion* Dahlbom, *Formicencyrus* Girault, *Leptomastidea* Mercet, *Leptomastix* Förster, *Metaphycus* Mercet, *Microterys* Thomson, *Pseudaphycus* Clausen, *Pseudoleptomastix* Girault, *Pseudococcobius* Timberlake, *Quaylea* Timberlake, *Rhopus* Förster, *Stemmatosteres* Timberlake, and *Zarhopalus* Ashmead.

HEMIPTERA (Bug eggs) — *Ooencyrtus* Ashmead.

COLEOPTERA (Ladybird beetles) — *Anisotylus* Timberlake, *Homalotylus* Mayr.

DIPTERA (Flies) — *Bothriothorax* Ratzeburg, *Meromyzobia* Ashmead, and *Tachinæphagus* Ashmead.

LEPIDOPTERA (Butterflies and moths) — *Ageniaspis* Dahlbom, *Copidosoma* Ratzeburg, *Encyrus* Latr., *Litomastix* Thomson, *Ooencyrtus* Ashm., *Psilophrys* Mayr.

HYMENOPTERA — *Achrysopophagus* Girault, *Copidosoma* Ratz., *Eusemion* Dahlbom, and *Quaylea* Timberlake.

Family SIGNIPHORIDÆ (Howard 1894) Vierick 1916 (Sig'ni-phor'i-dæ, from the Latin *signum*, standard, sign, pennon, + the Greek *φορός*, bearing; referring perhaps to the ovipositor). Signiphorid Parasites.

Minute, 0.5–1.0 mm., mostly yellow; primary, secondary, and tertiary parasites usually on scale insects, aleyrodids, and parasitic HYMENOPTERA which are usually included in the family ENCARTIDÆ.

Family EULOPHIDÆ Walker 1846 (Eu-loph'i-dæ, from the Greek *εὐλοφος*, beautifully crested, well plumed; in reference to the branched antennæ of some males). Eulophid Parasites, Plumed Wasps.

Minute species 1–3 mm. long, usually metallic or iridescent, which are parasitic and hyperparasitic on DIPTERA, LEPIDOPTERA, and HYMENOPTERA.

Family TETRASTICHIDÆ (Förster 1856) Walker 1871 (Tet'ra-stich'i-dæ, from the Greek τέτρα, four, + στίχος, a row or line; referring to the four scutal bristles). Tetrastichid Parasites.

Minute primary, secondary, and tertiary parasites, 0.8–2.0 mm. long; usually smooth, but the head and thorax sometimes sculptured; black or metallic blue, bronze, copper, or green and marked with yellow, brown, or red. Antennæ usually nine-segmented in females and 10-segmented in males; with or without one or two ring joints; club of females may be three- to four-segmented. Wings small, oval, without fringes of hair; cells lacking; submarginal vein with one to five bristles; stigmal vein present or absent; poststigmal vein usually absent. Scutel with four bristles in a row behind the middle and with or without two or four furrows. Abdomen sessile and pointed.

The members of this large cosmopolitan family are wholly parasitic on a great many groups of other insects and may attack the egg, larval, or adult stages. Females of certain species are parthenogenetic. The large genus *Tetrastichus* Haliday is known to parasitize eggs of moths and beetles and the larvæ of other parasitic HYMENOPTERA. *T. blepyri* Ashmead is commonly reared as a secondary parasite from coccids. *T. bruchophagi* Gahan is parasitic on the clover seed chalcid and *T. asparagi* Crawford on the eggs of the asparagus beetles. *Anozus* Förster has been reared from aphids, *Ootetrastichus betus* Perkins from the eggs of the sugar-cane leafhopper in Queensland and Hawaii, *Hyperteles* Förster and *Syntomosphyrum* Förster from the eggs of moths, and the remarkable *Thripoctonus russelli* Crawford from thrips in the United States.

Family APHELINIDÆ (Thunberg 1876) Viereck 1916 (Aph'e-lin'i-dæ, from the Greek ἀφ, from, + ἥλιος, the sun; in reference to the bright yellow colors). Sun Flies, Aphelinids, Scale Parasites.

Small to minute primary parasites, 0.5–1.5 mm. long; mostly yellow or black or brown marked with yellow. Antennæ eight-segmented. Tarsi four- to five-segmented. The members of this small and widely distributed family are parasitic within the bodies of aphids, coccids, and aleyrodids chiefly and are of considerable economic importance in control of these pestiferous insects.

The adults feed upon the honeydew of aphids and coccids and upon the exudates issuing from the punctures made in the bodies of the hosts by the ovipositor in egg-laying and for feeding purposes.

The most important genera are *Ablerus* Howard, *Aneristus* Howard, *Aphelinus* Dalman, *Aspidiotiphagus* Howard, *Coccophagus* Westwood, *Encarsia* Förster, *Eretmocerus* Haldeman, *Marietta* Motschulsky, *Mesidia* Förster, *Perissopterus* Howard, *Prospaltella* Howard, *Pteropterix* Westwood, and *Phycus* Howard.

Genera parasitizing aphids are *Aphelinus*, *Encarsia*, and *Mesidia*; those preying on coccids are *Ablerus*, *Aneristus*, *Aphelinus*, *Aspidiotiphagus*, *Coccophagus*, *Euanthellus*, *Marietta*, *Perissopterus*, *Prospaltella*, and *Phycus*; and those on aleyrodids are *Encarsia*, *Eretmocerus* and *Prospaltella*.

Aphelinus mali (Haldeman) is now a world-wide and effective natural enemy of the woolly apple aphid, while *A. jucundus* Gahan parasitizes other aphids and causes the bodies of the hosts to turn jet black; *A. diaspidis* Howard is one of the commonest parasites of armored scales. *Coccophagus lecanii* (Fitch) is an important enemy of unarmored scales and mealybugs and *C. gurneyi* Compere was introduced into California from Australia for the control of the citrophilus mealybug. *Eretmocerus serius* Silvestri is the most important natural check on the citrus black fly in tropical North America.

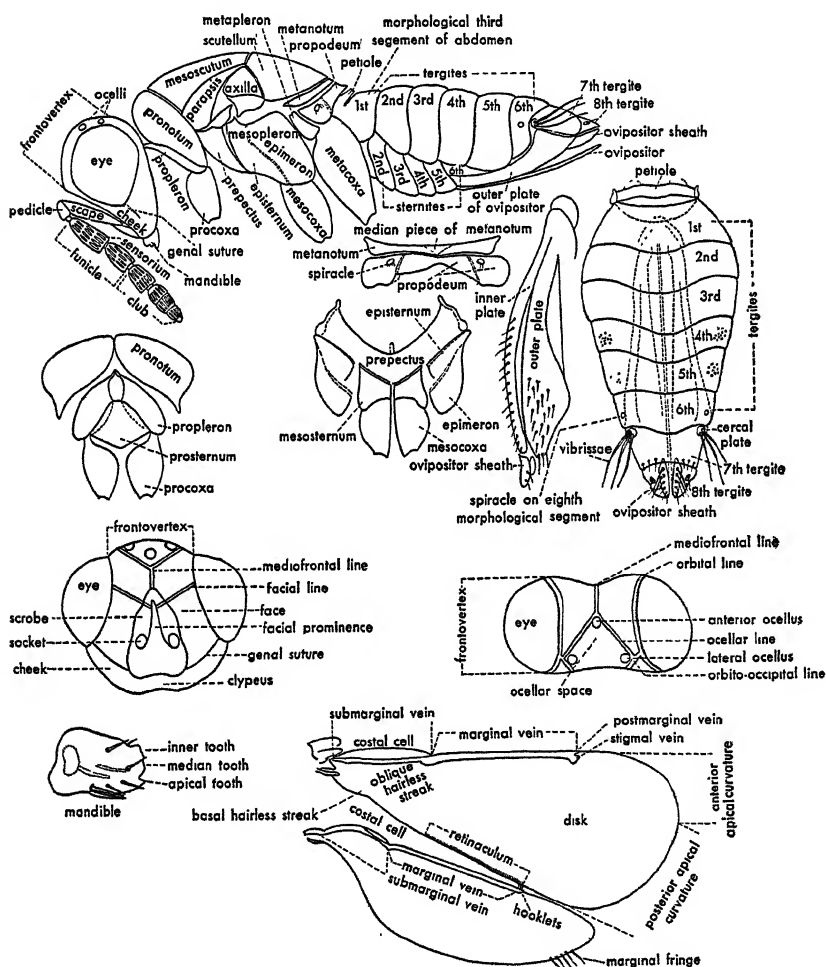


FIG. 230. Drawings of various parts of the chalcid, *Coccophagus malhusi* Girault, showing important structures. (After Compere, 1931.)

Family TRICHOGRAMMATIDÆ (Förster 1856) Walker 1871 (Trich'o-grammat'i-dæ, from the Greek *τριξ*, *τριχός*, hair, + *γράμματα*, a picture or letters; referring to the arrangement of the hairs on the wings). Trichogrammatid Egg Parasites.

Among the smallest of insects, 0.3–1.0 mm. long; black, dusky, or pale brown or yellow in color. Antennæ three-, five-, or eight-segmented including one ring segment; tarsi three-segmented, a character separating this from related families. Wings broad and fringed; hairs arranged in lines or bands; those on margins of hind wings longest; marginal and stigmal veins united. Ovipositor short and ventro-apical.

The members of this widely distributed cosmopolitan family number some 200 species and are parasitic on the eggs of other insects. Important genera are *Abbella* Girault, *Hydrophylax* Matheson and Crosby, *Lathromeris* Förster, *Oligosita* Walker, *Prestwichia* Lubbock, and *Trichogramma* Westwood. Genera reared from the eggs of dragonflies and damselflies are *Austromicron* Tillyard, *Hydrophylax*, and *Trichogramma*; from eggs of homopterous insects, *Abbella*, *Lathromeris*, *Oligosita*, and *Trichogramma*; from eggs of aquatic bugs, *Prestwichia*; from eggs of beetles, *Prestwichia* (aquatic) and *Trichogramma*; and from eggs of moths and butterflies, *Trichogramma*.

The outstanding important species is *Trichogramma evanescens* Westwood (= *minutum* Riley, *minutissimum* Packard, *odontotæ* Howard, *pretiosum* Riley), a pale or yellow species only 0.3 mm. long which is parasitic on the eggs of many orders of insects. It has been reared in connection with the biological control of the codling moth, the sugar-cane borer, the oriental peach moth, and other moths in the United States.

Prestwichia aquatica Lubbock swims under the water and parasitizes the eggs of aquatic bugs, beetles, and weevils in Europe, while *Austromicron zygopterorum* Tillyard swims and dives for the eggs of damselflies in Australia.

Family MYMARIDÆ Haliday 1840 (My-mar'i-dæ, from the Greek *μωμεῖω*, to blame, chide; in reference to their parasitic habits). Fairy Flies, Mymarid Egg Parasites.

Minute, mostly black and yellow insects which fly and jump with agility. They have eight- to 13-segmented antennæ without ring joints; those of the females terminate in a one- or two-segmented enlargement. Legs long and slender, the tarsi four- or five-segmented. Wings narrow and fringed; the bases of the very slender hind pair stalked. Abdomen sessile, subsessile, or petiolate; nearly all sternites visible; ovipositor issuing just before the extremity.

In this family is to be found the smallest hymenopteron and, many naturalists believe, the smallest insect. This is *Alaptus*¹ *magnanimus* Annandale, only 0.21 mm. long.

¹ This is probably the *Elaphis* referred to as the smallest insect by Wells, Huxley, and Wells (1934, p. 943). *Alaptus excisus* Westwood, first reported to be only about 0.17 mm. long, has been found to be 0.50 mm. long. It is rather remarkable that the nearest competitors are beetles of the family TRICHOPTERYGIDÆ, one species of which is no more than 0.25 mm. long. These beetles also have fringed wings, but are free-living fungus feeders.

The family consists of some 15 genera and about 200 species and is cosmopolitan in distribution. The adults oviposit in the eggs of many insects, and the larvæ are parasitic on them and are considered beneficial because of their destruction of many serious pests of agricultural crops. One of the most remark-

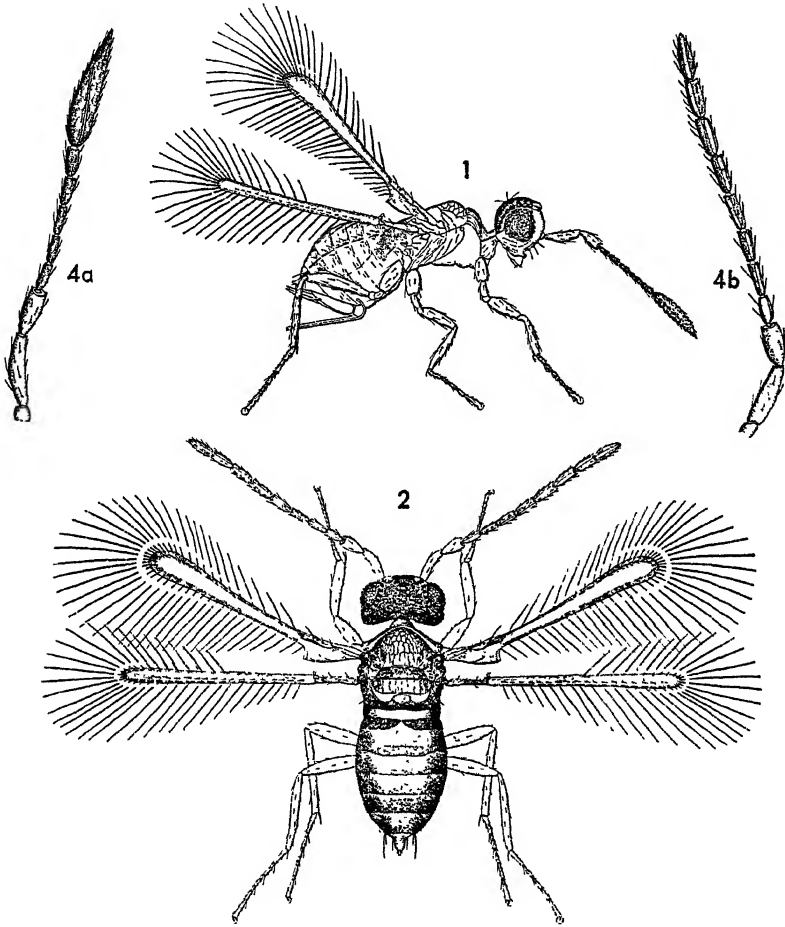


FIG. 231. A mymarid parasite, *Metalaptus torquatus* Melanotti. It is less than 0.3 mm. long and is one of the smallest insects. (After Melanotti, 1917.)

able of these is *Paranagrus obtabilis* Perkins, a very effective parasite of the sugar-cane leafhopper in Hawaii and the tropical Pacific area.

The most important genera are *Alaptus* Westwood, *Anagrus* Haliday, *Anaphes* Haliday, *Anaphoidea* Girault, *Camptoptera* Förster, *Gonatocerus* Nees, *Leimacis* Förster, *Mymar* Curtis, *Ooctonus* Hal., *Paranagrus* Perkins, and

Polynema Haliday. Most of these may be grouped according to the hosts as follows: *Polynema* on ODONATA; *Alaptus* and *Polynema* on CORRODENTIA; *Polynema* on ORTHOPTERA; *Alaptus*, *Anagrus*, *Anaphes*, *Camptoptera*, *Gonatocerus*, *Leimacis*, *Paranagrus*, and *Polynema* on HOMOPTERA; *Polynema* on HETEROPTERA; *Alaptus*, *Anaphes*, *Anaphoidea*, and *Gonatocerus* on RHYNCHOPHORA.

Certain species of *Polynema* are known to enter the water and swim with their wings and legs in order to seek out and parasitize the eggs of dragonflies and backswimmers. Both sexes emerge from the host eggs in the same manner.

VII. Superfamily SERPHOIDEA Viereck 1916

(Serph-oi'de-a, from the Greek *σέρφος*, a small winged insect.)
Pointed-tailed Wasps, Proctotrupid Wasps.

Minute to small, slender, dark, or metallic primary and secondary parasitic wasps with straight or elbowed antennæ; greatly reduced venation with but few closed cells; abdomen pointed and with conspicuously or inconspicuously carinated or keeled lateral margins; ovipositor tubular and issuing from extreme tip of abdomen.

LIST OF FAMILIES

- | | |
|----------------------|------------------------|
| 71. Family DIAPRIIDÆ | 77. Family PELECINIDÆ |
| 72. " SERPHIDÆ | 78. " SCLEROGIBBIDÆ |
| 73. " CALLICERATIDÆ | 79. " ROPRONIIDÆ (also |
| (CERAPHRONIDÆ) | listed with ICHNU |
| 74. " SCELIONIDÆ | MONOIDEA) |
| 75. " PLATYGASTERIDÆ | 80. " HELORIDÆ |
| 76. " EMBOLEMIDÆ | 81. " VANHORNIIDÆ |
| | 82. " DICROGENIIDÆ |

Family SERPHIDÆ¹ Kieffer 1909 (Ser'phi-dæ, from the Greek *σέρφος*, a small winged insect). Pointed-tailed Wasps.

Minute to small wasps, 2.5–10.0 mm., mostly dark or brownish, yellowish, or reddish, some metallic. Antennæ inserted at middle of face, 13-segmented with one ring segment. Mesonotum smooth or rugose, with or without median carina. Fore wings with stigma and usually only one very small closed radial cell. Abdomen with short petiole; segment II much longer than others; pointed or deflexed; ovipositor formed by modified apical segments, straight, retractile.

A small family of important parasitic insects which prey upon a wide variety of other insects and small diplopods; cosmopolitan in distribution. Important genera are *Serphus* Schrank (*Proctotrupes* Latr.) *Disognus* Förster, and *Exalonyx* Kieffer.

¹ Also known as PROCTOTRUPIDÆ (Latreille 1802) Stephens 1829. The type genus *Serphus* was erected by Schrank in 1780, whereas *Proctotrupes* was not established by Latreille until 1796.

Family SCELIONIDÆ Haliday 1840 (Scel'i-on'i-dæ, from the Greek σκέλος, the leg, rib, side; referring to the distinctly keeled or carinated sides of the abdomen). Scelionids, Egg Parasites.

Minute to small, 0.45–5.00 mm., mostly dark, shining, naked species. Antennæ elbowed, normally simple in male and clavate in female; usually 12-segmented, rarely seven- to eight-segmented when segments of club are fused together. Scutellum present or absent; postscutellum armed or unarmed. Tibiæ normally with single spur, that of fore pair divided. Wings present or rarely absent; stigma absent; costal or stigmatic vein distinct and short or long. Abdomen elongate or oval; sharply margined or keeled on sides; segment I with or without a horn.

This large and widely distributed family is of great economic importance to agriculture because the members are parasitic in the eggs of many destructive insects. The remarkable phenomenon of phoresy occurs in the case of *Rielia manticida* Kieffer, the adult females of which attach themselves to the body of the praying mantid, *Mantis religiosa* Linn., shed their wings, and are carried until the mantid lays her eggs when the parasite inserts its eggs into the oötheca of the mantid and the larvæ become endoparasitic on the eggs of the host.

The eggs of spiders and of many orders of insects are subject to parasitism by these tiny insects, for instance the eggs of spiders by members of the genera *Acoloides* Howard, *Acolus* Förster, and *Bæus* Haliday; those of grasshoppers, katydids, and crickets by *Barycomus* Förster, *Cacellus* Ashmead, *Scelio* Latr., and *Sparaisson* Latr.; those of mantids by *Rielia* Kieffer; of bugs by *Aradophagus* Ashm., *Eumicrosoma* Gahan, *Hadronotus* Förster, *Telenomus* Haliday, and *Trissolcus* Ashm.; of beetles by *Proscantha* Nees; of butterflies and moths by *Phanurus* Thomson, *Prophanurus* Kieffer, and *Telenomus* Haliday; and of ants by *Idris* Förster.

Family PLATYGASTERIDÆ (Westwood 1840) Ashmead 1900 (Plat'y-gaster'i-dæ, from the Greek πλατύς, broad, wide, + γαστήρ, belly, stomach; referring to the broad, laterally keeled abdomen). Platygasterid Parasites.

Minute to small, 0.6–4.0 mm., mostly black or brown, with reddish or yellowish markings; many shining and lustrous. Antennæ usually eight- to 10-segmented or rarely less; club simple or four-segmented. Tarsi four- or five-segmented; tibiæ one-spurred. Wings usually without veins or the fore pair may have a free-ending radius vein. Abdomen with sharp lateral keels or margins, sometimes lengthened. The members constitute a large and widely distributed family of primary and secondary parasites. The eggs may be inserted into the eggs of the host but usually hatch in the larvæ of the latter. The larvæ may be free living or occupy cysts in the bodies of the host. Polyembryony is not unusual. The hosts consist chiefly of gall gnats, midges, crane flies, and other dipterous forms, and also leafhoppers and aleocharids.

Some important genera are *Amblyaspis* Förster, *Amilus* Haldeman, *Inostemma* Haliday, *Isocybus* Förster, *Polygnotus* Förster, *Polymecus* Förster, and *Platygaster* Latr. *Platygaster hiemalis* Forbes and *P. vernalis* (Myers) are

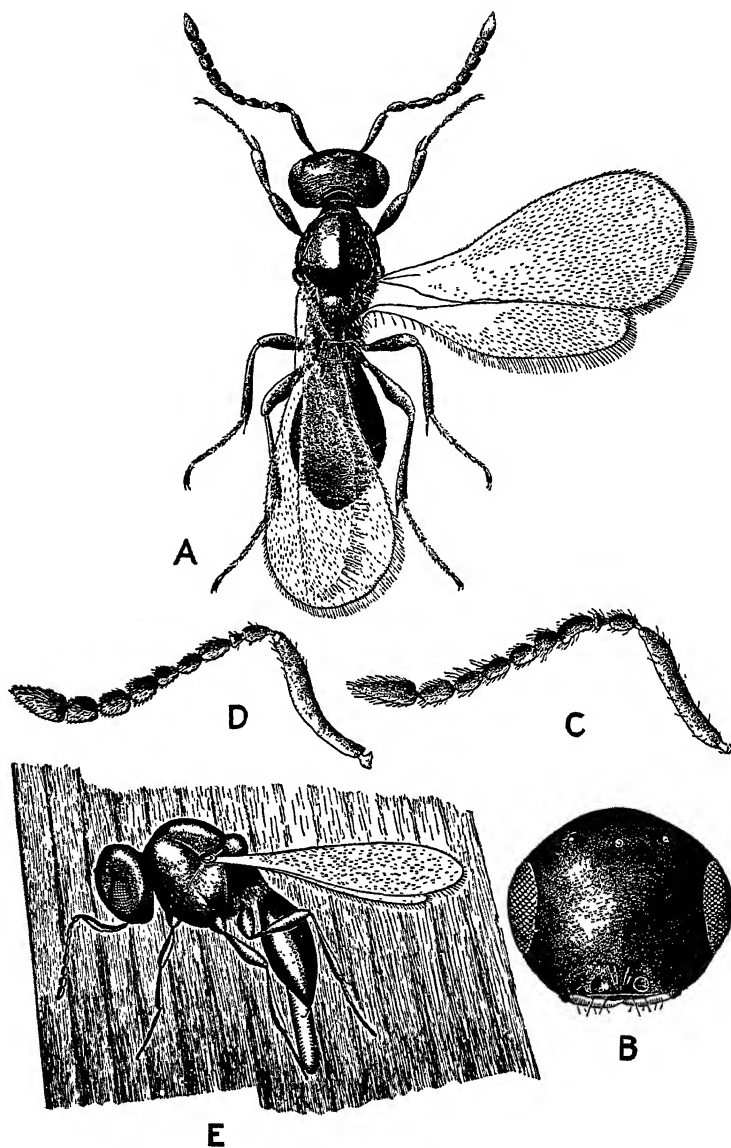


FIG. 232. The Hessian fly parasite, *Platygaster hiemalis* Forbes. A, adult female; B, front aspect of head of same; C, antenna of male; D, antenna of female; E, female ovipositing in Hessian fly eggs on a wheat leaf. (After Hill, U.S. Bur. Ent., 1926.)

the two most important parasites of the Hessian fly in North America (Sweetman).

Family PELECINIDÆ ¹ Haliday 1840 (Pel'e-cin'i-dæ, from the Greek πελεκῖνος, a water bird, a pelican; because of its peculiar form although it bears no resemblance to that bird).

Very long and slender species in which the abdomen of the female may attain a length four or five times that of the combined head and thorax. This is a very small family of what is thought to be a primitive type of insect. The very interesting *Pelecinus polyturator* Drury of North and South America is the best known species although a rare one in collections. The females vary from 50–60 mm. and the males from 15–22 mm. in length. The larvæ are parasitic on white grubs.

VIII. Superfamily BETHYLOIDEA (Förster 1856) Schröder 1925

(Beth'y-loi'de-a, new Latin from *Bethylus* Latreille 1802; without explanation.) Bethyloid Wasps.

Minute to small, dark-colored, black or metallic bronze wasps, usually 1–3 mm. and rarely more than 10 mm. long; hind wings with poorly developed or distinct anal lobe; pronotum extending back to base of wings in most species; discoidal cells obsolete or the first cell petiolate; venation lacking in hind wings. Parasitic.

83. Family BETHYLIDÆ Haliday 1840. Bethylid Wasps

84. " DRYINIDÆ Haliday 1833, 1840. Dryinids, Dryinid Wasps

85. " CLEPTIDÆ (Leach 1815) Dahlbom 1854. Cleptids

KEY TO FAMILIES

1. Head broad, transverse, globose, or subquadrate; antennæ 10-segmented in both sexes; fore tarsi of female usually chelate or pincers-like; female often apterous and with thorax nodose **DRYINIDÆ**
Head elongate or oblong; antennæ 12- to 13-segmented; fore tarsi normal; females apterous or winged 2
2. Abdomen with seven or eight visible dorsal segments; hind wings with anal lobe conspicuous **BETHYLIDÆ** p. 666
Abdomen of females with four and males with five visible dorsal segments; hind wings with inconspicuous anal lobe — represented by a minute marginal notch. Parasitic on sawfly larvæ. Holarctic
CLEPTIDÆ

Family DRYINIDÆ Haliday 1833, 1840 (Dry-in'i-dæ, from the Greek δρύϊνος, relating to the oak tree; application uncertain). Dryinids, Dryinid Wasps.

Minute to small, ant-like, winged and wingless species, measuring from 2.4–5.0 mm. in length. Head large, broad, and transverse. Antennæ arising

¹ This family has been made a superfamily PELECINOIDEA by Handlirsch 1909 and a suborder in 1925.

near the mouth, 10-segmented. Thorax long and slender. Forelegs long; tarsi of females chelate (except in *Anteon* Jurine, *Aphelopus* Dalman, *Heterolepis* Nees) for capturing and holding living prey. Middle and hind legs small. Wings present or absent; veins and cells reduced in numbers; stigma oval or narrow; basal cells present or absent. Abdomen frequently small and globular or egg-shaped with short or distinct petiole. The females are frequently apterous and have a long slender thorax and sometimes two nodes on the petiole. The larvæ are endoparasitic in the abdomen of the host, occupying a very large dark or yellowish cyst that protrudes between the segments. Pupation is normally on the food plant of the host or in the soil. The effects on the host are similar to stylopization. Some forms are parthenogenetic. The adults are hunters and are predacious on living leafhoppers, froghoppers, treehoppers, spittle bugs, and other homopterous insects. *Aphelopus* is recorded as predatory on the chrysalids of butterflies.

The family, consisting of some 400 species, is mostly Holarctic with a few tropical forms. The most important genera are *Anteon* Jurine, *Aphelopus* Dalman, *Chelogynus* Haliday, *Dicondylus* Haliday, *Dryinus* Latr., *Gonatopus* Ljungh, *Heterolepis* Nees, *Laberius* Kieffer, *Paradryinus* Perkins, and *Pseudogonatopus* Perkins.

In the North American *Gonatopus contortulus* Patton the females are ant-like, wingless, shiny black, 3-4 mm. long, and have very long forelegs and long pincer-like or chelate claws. The males are winged. The larval sac is oval, shiny black, and protrudes exteriorly from the abdomen. The mature larva leaves the sac and pupates in an oval white cocoon 4.5 by 0.5 mm. which is attached to grasses or other plants. The very active females stalk their prey which is seized with the chelate forelegs and held while the egg is inserted, usually into the venter. They also devour numbers of the hosts. They are sexual or parthenogenetic. The larvæ hibernate in the cocoons. This species is parasitic and predacious on leafhoppers. Other North American species are *Gonatopus ombrodes* (Perkins) of the Rocky Mountains, *G. californicus* Ashmead of the Pacific coast, and *G. flavifrons* Ashm., *G. decipiens* Provancher, and *G. typhlocybæ* Ashm. of the eastern states. *Dryinus* is represented in the eastern states by *D. bifasciatus* Say, *D. nigrellus* Brues, and *D. ormenidis* Ashm.

In Australia there are 38 species and in New Zealand, eight species.

Family BETHYLIDÆ Haliday 1840 (Be-thyl'i-dæ; see derivation under superfamily). Bethylid Wasps.

Small to medium-sized, usually metallic-bronze species, with sexual dimorphism in which either sex or both sexes of a species may include winged and apterous individuals. Head elongate, transverse, or subglobose. Antennæ 12- to 13- or 14- to 15-segmented, situated on frontal shelf-like prominences near the mouth. Eyes naked or hairy, often greatly reduced in size and the inner margins parallel. Mandibles large and strong. Legs often strong. Wings with veins reduced and stigma present; fore wings with several open cells and usually with closed costal, basal, and marginal cells; radius present or absent;

hind wings with basal cell and without anal lobe; both pairs rarely absent. Abdomen petiolate and with seven or eight visible dorsal segments. Parthenogenesis is said to occur in some species. The larvæ are commonly endo- or ectoparasitic on the paralyzed or dead larvæ of beetles, moths, and butterflies.

The best known species in Australia, *Goniozus antipodum* Westwood, is, according to Tillyard (1926), parasitic on the larvæ of the codling moth and related species, while another Australian species, *Sierola antipodum* Ashmead, is parasitic in the galls of cecidomyiid midges. The family is widely distributed and is best developed in tropical and subtropical regions. The most important genera are *Bethylus* Latr., *Epyris* Westwood, *Goniozus* Förster, *Isobrachium* Förster, *Mesitius* Spinola, *Prisocera* Klug, and *Sclerodermus* Latr.

The small *Epyris californicus* (Ashmead), which is thought perhaps to parasitize the larvæ of tenebrionid beetles, has been known to sting and inflict severe pains and complications on humans in the lowland delta region of California.

IX. Superfamily FORMICOIDEA

(From the Latin *formica*, an ant.) German, Ameise. French, Fourmi.
Ants.

These are among the most familiar insects, being cosmopolitan in distribution, occurring from the arctics to the tropics, in the deserts, forests, fields, mountains, along the seashores, and in towns, cities, and the abodes of man. They are dominant among insects and in individuals outnumber all other land animals. The adults are minute to small, measuring from 0.5–25.0 mm. in length, social, polymorphic insects which have evolved a definite caste system consisting chiefly of true sexes and infertile female workers, and soldiers with many modifications of these types. Body smooth, hairy, pubescent, spined, striated, reticulated, sculptured, or tuberculate; segmentation distinct, with pronounced head, thorax, and abdomen. Colors mostly somber, being black and various shades and combinations of yellow, brown, and red. Integument thin and elastic or leathery, or thick, hard, and brittle. Head variable, usually large, broad, rarely larger than the rest of the body in certain soldiers; free and extremely mobile. Antennæ geniculate in the sexual and infertile females and simple in males; four- to 13-segmented (some males have simple 13-segmented antennæ); *scape*, or basal portion, usually consists of a single, very long segment whereas the *funicle*, *flagellum*, or apical portion may be four- to 11-segmented; the apical two or three segments may be considerably enlarged. Eyes small, vestigial, or rarely absent. Ocelli or stemmata consist of three on the vertex or none in workers. Mouth parts normally well developed and sometimes very powerful. *Labrum* — vestigial. *Mandibles* — exceedingly variable, broad and heavy or long and formidable, straight or curved, simple or toothed, meeting in a straight line or crossing. *Maxillæ* — normal; *maxillary palpi* — one- to six-segmented. *Lacinia* — simple. *Labium* — with *mentum*, *submentum*, *median glossa*, and two small *paraglossæ*; *labial palpi* — one- to four-segmented. *Thorax* — well defined and elongated owing to the fusion of

the first abdominal segment or epinotum with the metathorax; prothorax very small in some primitive forms; with a pair of spiracles each on the mesothorax, metathorax, and the epinotum. *Legs* — well formed; *trochanters* — undivided; *tibial spurs* — well developed; the large and pectinate spur of the forelegs is used as a *strigilis* or antenna cleaner; *tarsi* — five-segmented and terminated by a pair of strong claws. *Wings* — two pairs present in most of the sexuales but

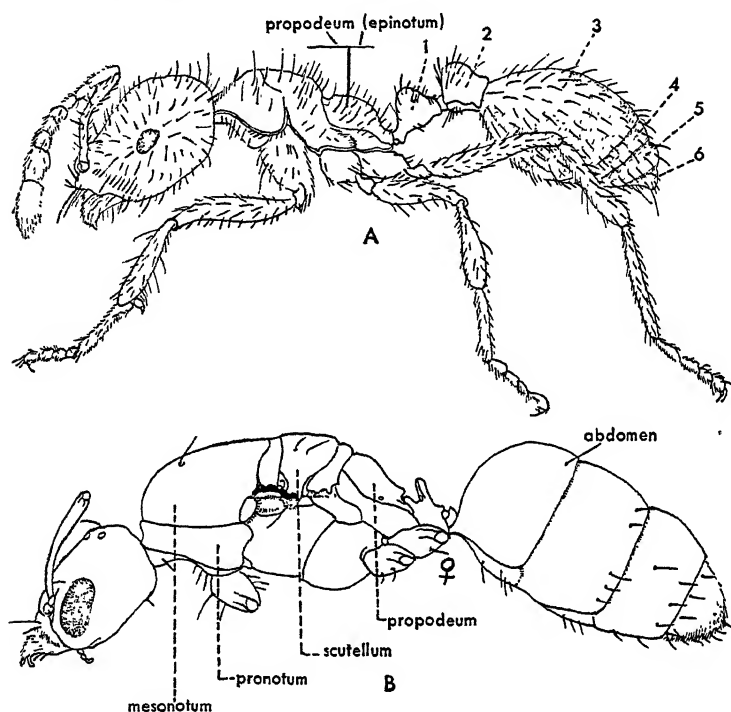


FIG. 233. Drawings showing some characters of ants. A, fire ant, *Solenopsis geminata* (Fab.); B, Argentine ant, *Iridomyrmex humilis* Mayr.

always absent in the sterile or worker caste; venation simple with one or two cubital and one discal or discoidal cell present; mated females either bite or rub off the wings, leaving irregular stubs. *Abdomen* — follows the epinotum which is fused to the metathorax; the abdomen is conspicuously constricted or petiolate. The *pedicel* may be simple, in which case it is known as the *petiole*, or two-segmented, in which case the second segment is called the *postpetiole*. Each segment may support one or two dorsal nodes or as many erect or inclined scales. The remaining large part of the abdomen, the *gaster*, may consist of seven or eight segments, the male having one more segment than the female. There are eight pairs of spiracles on the abdomen, including the epinotum on segments I to VIII inclusive. Stridulating organs, consisting of a file on the

postpetiole and a stridulatory surface on the first segment of the gaster, occur in a number of genera but are absent in others.

The eggs are usually very small, scarcely ever much more than 0.5 mm. and often less; white or pale yellow and either long, slender, and cylindrical-ovate or regularly oval in form; smooth and with thin delicate membranous covering.

The larvæ are apodous, blind, and eruciform with well-developed, though often small, head and soft, distinctly segmented body consisting of three thoracic and usually 10 abdominal segments. The form may be cylindrical or more often narrowest at the anterior end and gradually enlarging posteriorly. The surface is smooth, hairy, spiny, tuberculate, or with capitate or coiled spring-like hairs. They are cared for in the nest by certain workers or nurses and are moved about to take advantage of moisture and temperature conditions. They are fed liquids regurgitated from the mouths of the workers and masticated bits of insects and other small animals and hyphæ of fungi specially reared by some ants.

Pupæ are free and naked or enclosed in oval parchment-like cocoons spun by the larvæ. The more primitive groups are enclosed in cocoons while the higher ones are naked. The cocoons are usually evident whenever a nest is opened. They are often mistaken for ant eggs and are regularly sold as such for bird food in the bird shops of Europe and North America.

POLYMORPHISM

According to Imms (1934), there are as many as 29 different types of individuals among the various castes.

CASTES

All ants are social insects, no truly solitary species being known. The important castes are chiefly composed of the following kinds of individuals.

1. Sterile or infertile females.

- (1) *Workers* or *ergates* (er'gates) — apterous forms which are normally the smallest members of the nest. They are variable in size and while some species are polymorphic most are dimorphic; eyes small; ocelli minute or absent; mandibles, antennæ, and legs well developed; sting present or absent. Unusually large members are called *macrergates* and dwarf individuals, *micrergates*. *B-females* are workers in which the antennæ, legs, and pilosity of the bodies are exaggerated. Individuals having the size and form of the gaster of the worker combined with the thorax of the fertile female are known as *pseudogynes*. *Gynecoids* are members which, if sufficiently fed and cared for, are capable of laying fertile eggs and replacing the queens. *Repletes* or *plerergates*, which are commonly called honey ants or honey pot ants, are capable of engorging themselves with liquid food so as to become large inactive reservoirs of honey which may be held in reserve for long periods

of time and yet be available to the other members of the colony as needed.

- (2) *Soldiers* or *dinergates* are workers with large heads and mandibles that are utilized for crushing seeds and other hard foods and for fighting. *Desmergates* are intermediate between the workers and the true soldiers. *Pterergates* are workers or soldiers with rudimentary wings.
2. Fertile females, gynes (jīn'ēs), or queens — large individuals which may attain enormity among tropical species; with large gaster and well-developed reproductive organs; antennæ and legs relatively short; mandibles normal; winged, deälated, or apterous. Unusually large specimens are known as *macrogynes* and dwarfed ones as *microgynes*. In certain dimorphic forms those that are apterous and resemble workers are the *ergatogynes*. Rare individuals that have the external secondary characters of both male and female sexes combined laterally or otherwise are called *gynandromorphs*, a condition noted in species in widely separated orders of insects. Forms with unusual development of the antennæ, legs, and body pilosity are known as *A-females*.
3. Males or aners (ā'ners) — sexual individuals with well-developed sensory and male reproductive organs and genitalia; head small and round; mandibles reduced; antennæ long and slender. Especially large individuals are known as *macraners*; dwarfs as *micraners*; those parasitized by eucharids as *phthisaners*; those parasitized by nematodes as *mermithaners*; those resembling workers as *ergataners*; and those appearing like fertile females as *gynæcaners* (in the genera *Anergates* Forel and *Epæcus* Emery).

MATING AND NESTS

Winged sexes of a given species swarm at the same time and mate during or at the end of the nuptial flight. After mating the males die, whereas each female disposes of her wings by nipping or rubbing them off and then proceeds to find or make a small burrow or chamber in the earth or other suitable nesting site in which she seals herself and remains in solitary confinement until her eggs are matured, laid, hatched, and the larvæ fed and tended until they reach maturity. Food is furnished from the mouth of the parent, and by the time these first undernourished workers excavate an opening to the outer world in search of food the mother is almost depleted. From this time on the queen continues to lay fertilized eggs throughout her lifetime; the workers care for the young and feed the parent and henceforth the colony increases apace. Certain fertilized queens like those of the red wood ant, *Formica rufa* Linn., are unable to found a colony without the aid of workers and must return to their old nests and thereby add to the number of queens, while mated queens of the narrow-headed ant, *F. exsecta* Nyal, may be accompanied by a group of workers to a new near-by site.

The important facts concerning a nest or formicarium may be summarized as follows:

1. Queens once fertilized reproduce almost continuously in the tropical and subtropical regions and cease only during the colder season in their most northerly and southerly limits. They have been known to live at least 15 years.
2. Workers enlarge and maintain the nest, gather the food, feed and nurse the queen and young, and defend the formicarium.
3. Colonies may continue to increase in size for many years. The population may vary from a few thousands up to 500,000 (Forel 1874, Wheeler 1926).
4. Nests are of many types and variously located. Those of most species consist of excavated galleries, chambers, and habitations in the soil. The excavated materials, leaves, and other plant debris may be heaped around or near the entrances, forming craters or mounds. Nests of *Formica rufa* may attain a height of from 2 to 5 ft. and a diameter of from 3 to 8 ft. Such mounds not only cover and protect the subterranean galleries but are themselves inhabited. When disturbed, certain of these mound-building species discharge sufficient quantities of formic acid to form a vapor that makes the immediate vicinity very uncomfortable for man and other mammals. Nests may also be established in stems, seeds, leaf petioles, thorns, and tied leaves of living plants and in hollow twigs, dead galls, logs, and stumps. They may be made of paper-like materials and attached to and suspended from trees, rocks, and other objects. Certain species nest in or in close proximity to the nests of other species as, in the case of *Leptothorax emersoni* Wheeler, in the nests of *Myrmica* spp. in eastern North America. Such relationship in compound nests is called *plesiobiosis* by Wheeler.

FOOD

Ants are for the most part general feeders and consume both animal and vegetable food either as solids or liquids. Their food habits may be briefly summarized as follows:

1. *Carnivorous* — especially members of the subfamilies PONERINÆ and DORYLINÆ, but members of other subfamilies also feed on animal matter. They feed on insects, spiders, and other small invertebrates and rarely also upon small and even large mammals which are overwhelmed and killed.
2. *Herbivorous* — includes members of all groups except the two carnivorous subfamilies mentioned above. These ants feed upon seeds, coatings of seeds, fungi, fruits, and other vegetable products.
3. *Omnivorous* — members of the higher groups DOLICHODERINÆ, FORMICINÆ, and MYRMICINÆ which, while largely vegetarians, also feed upon live and dead animal matter that may be available. They are also very fond of the nectar of flowers and other sweet glandular

secretions of plants, honey, and honeydew, as well as the exudates from wounds of plants.

4. *Trophallactic* — a mutual exchange of food in which the workers feed the larvæ and lick off exudates discharged from certain glands on the bodies of the latter.

OTHER INSECTS ASSOCIATED WITH ANTS

Ant nests and even ants on the march attract a wide variety of other insects which are temporarily, intermittently, or permanently associated with them. These so-called guests are good, bad, and indifferent in so far as the welfare of the ants is concerned. They are usually segregated into the following categories, although this classification is by no means exact and complete:

1. *Symbionts* — insects living in symbiosis with the ants. These include fulgorids, membracids, psyllids, aphids, coccids, and other homopterous forms, and certain caterpillars of the lycænid butterflies. These insects are afforded protection by the ants and benefit them by producing honeydew and other secretions eagerly sought by their hosts. Such insects are distinguished from the symphiles or true guests because of their ability to exist wholly outside the nest and to spend only a part of their life history in the colony.
2. *Myrmecophiles, guests, or messmates* — more or less permanent inhabitants of the nests. They include members of many orders, especially the COLEOPTERA, which are represented by no less than 1,000 to 1,200 species. These inquilines may be grouped for convenience into:
 - (1) *Synechthrans* — unwelcome guests which, because of their agility, secretiveness, and camouflage, are able to maintain themselves as permanent boarders. They are mostly scavengers and predators many of which mimic the particular ants with which they are associated. They consume much of the refuse of the colony, steal food from the mouths of the workers, and kill and devour the weak, maimed, and even normal workers. Staphylinid beetles are the most representative of this class, and the ants are decidedly hostile to them.
 - (2) *Synoëkeles* — guests unnoticed or tolerated because the ants are unable to deal effectively with them. They are mostly harmless scavengers or nuisances or strigilators and are classified by Wheeler as being:
 - a. *Neutrals* — scavengers that are not mimetic: mites; collembolens; staphylinid, trichopterygid, chrysomelid, and scarabæid beetles; phorid and syrphid flies; and caterpillars of certain microlepidopterans.
 - b. *Mimetics* — various insects that mimic their hosts to a remarkable degree. They are most abundant among the doryline ants and are best represented by members of the

coleopterous families STAPHYLINIDÆ, HISTERIDÆ, and CETONIIDÆ.

- c. *Myrmecocleptics* — a special term used by Wheeler for the lepismids, *Atelura formicaria* Heyden of Europe and *A. wheeleri* Escherich of Texas and Mexico which steal regurgitated food as it passes from the mouth of one ant to that of another.
 - d. *Strigilators* — another term employed by Wheeler to designate certain insects that lick the surface or groom certain ants for their body secretions. There are several hundred species of these guests, including crickets, cockroaches, staphylinid beetles, and other small insects. Among the best known are the tiny ant-loving crickets belonging to the genus *Myrmecophila* Latr. of which there are two species in Europe, five in North America, two in South America, and one each in North Africa, India, Bintang Islands, and Australia.
- (3) *Symphiles*, *true guests*, or *myrmecoxenes* — insects which are welcomed by the ants and may be reared, fed, and groomed for their secretions, which are eagerly sought by the ants. They are mostly beetles; chiefly staphylinids, paussids, and clavigerids, with fewer representatives of brenthids, silphids, and tenebrionids. Some of these beetles are clothed with red or yellow hairs from the tufts of which the delectable fluids are obtained. To rear the larvæ of these guests the ants will even feed them their own eggs and young.
- (4) *Social parasites* — include such other ants as the European *Anergates atratulus* Schrank which has lost its worker caste and the queens of which lay their eggs in the nests of *Tetramorium cæspitum* (Linn.), whose workers rear the young of the intruder.
- (5) *Parasites* — Ants are subject to a considerable amount of parasitism, certain types of which it would appear might be avoided. These seemingly wise insects, however, are apparently unaware of this most terrible aspect of nature.
- a. *Ectoparasites* — mites belonging to the genera *Antennophorus* Haller, *Cillibano* Heyden, *Uropoda* Latr., and *Urodiscella* Berlese; thorictid beetles; phorid flies; and chalcids of the genus *Orasema* Cameron.
 - b. *Endoparasites* — the nematodes of the genus *Mermis* Dujardin, which attack both larvæ and adults; phorid flies, including *Plastophora curriei* Malloch of North America, which parasitize the heads; conopid flies, which infest the bodies; the styloid *Myrmecolax* Westwood, found in the bodies, and many hymenopterous braconid, chalcid, and proctotrypid parasites, infesting the gaster.

- (6) *Slave-making ants* — a number of species of ants that conduct what appear to be well-organized raids against other ants and carry off the pupæ which are borne to the nests of the raiders. The resultant adults become workers or slaves of the captors. In some cases the slaves are not essential workers while in others they are necessary to make the nests and to rear and feed the young of the slave-making species. Certain species may even adopt or enslave a mated queen of a different species.

86. Family FORMICIDÆ (Latreille 1802)¹ Stephens 1829

KEY TO IMPORTANT SUBFAMILIES²

(Workers)

1. Cloacal orifice ventral, slit-shaped; sting well developed or vestigial; abdominal pedicel consisting of one or two segments 2
 Cloacal orifice terminal, circular, surrounded by a fringe of hairs; abdominal pedicel consisting of only a single segment; no constriction between the first and second gastric segments; pupæ usually enclosed in cocoon **FORMICINÆ** p. 680
2. Sting developed, sometimes very small but nevertheless exsertile; abdominal pedicel consisting of one or two segments; when of only one, a distinct constriction between first and second gastric segments 3
 Sting vestigial; abdominal pedicel consisting of a single segment; no constriction between first and second gastric segments; anal glands which produce a secretion with a peculiar rancid-butter odor (*Tapinoma* odor) often present; pupæ naked **DOLICHODERINÆ** p. 676
3. Pupæ always enclosed in cocoons; abdominal pedicel consisting of a single segment; gaster with a distinct constriction between its first and second segments; frontal carinæ separated or close together; when close together, dilated to form oblique or horizontal laminæ partly covering insertions of antennæ **PONERINÆ**
 Pupæ naked; abdominal pedicel consisting of two segments 4
4. Frontal carinæ very close together, almost vertical, not at all covering antennal insertions; eyes always very small or absent; tropical and subtropical **DORYLINÆ** p. 676
 Frontal carinæ of a different conformation and covering the antennal insertions; eyes rarely vestigial or absent. Cosmopolitan **MYRMICINÆ** p. 678

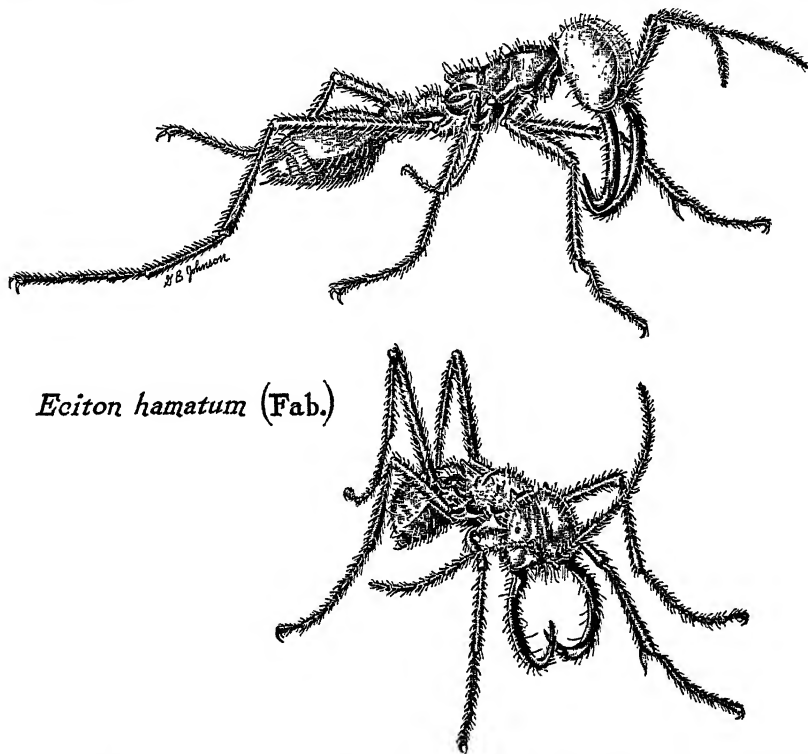
Subfamily PONERINÆ Smith 1851 (*Po-ner'i-næ*, from the Greek *πονιρός*, bad, painful; because of their fierceness). Keleps, Bulldog Ants, Jumping Ants, Ponerine Ants.

These ants vary from the minute temperate species only 2.5 mm. long to the Australian bulldog ants which may be 25 mm. in length. They are considered to be the most primitive ants and are represented by three castes of which all

¹ Also known by the name of *HETEROGYNA* Cresson 1887.

² After Wheeler, *Hymenoptera of Connecticut*, pp. 579-580, 1916. W. M. Wheeler, "The Subfamilies of Formicidæ," *Psyche*, 20, pp. 46-55, 1920.

the members of each are about the same size. Head with the frontal carinae close together or separated and in the latter case partially covering the insertions of the antennae. Mandibles sometimes greatly enlarged, sharp, and curved. Fore wings with cells *r* and *m* closed. Abdomen with single-segmented petiole and a constriction between segments I and II of the gaster. Sting well developed. Male genitalia partly retractile. Carnivorous adults feed the larvæ with



Eciton hamatum (Fab.)

FIG. 234. Soldiers of the driver or legionary ant, *Eciton hamatum* (Fab.). This remarkable and ferocious ant is indigenous to the tropical forests of North and South America.

masticated insect remains. Pupæ enclosed in cocoons. The nests are subterranean and small, consisting of only 20 or 30 individuals.

The family is a small one and widely distributed but reaches its highest development in the tropics and especially in Australia, which has 30 genera and 137 species (Tillyard 1925). The important genera are *Cerapachys* F. Smith (tropical American), *Myrmecia* Emery (Australian), *Odontomachus* Latr. (tropical American), *Ponera* Latr. (cosmopolitan), and *Proceratium* Roger (tropical American).

The red bulldog ant, *Myrmecia gulosa* (Fab.), of Australia, a large red, yellow, and black species in which the workers are 20 mm. and the queens 25 mm. long,

are ferocious stinging and biting ants that are greatly respected by animals as well as by the native bushmen and the whites alike. The adults of the smaller **Australian jumper**, *M. nigrocincta* Smith, 12.5 mm. in length and reddish-yellow, are also fierce biters and active jumpers that erect mounds in the dry forests. *Ponera coarctata* Latr. and *P. punctatissima* Roger are small species only 2.5–3.0 mm. long. *P. pennsylvanica* (Buckley) is a North American representative that nests under stones, rotten logs, and other debris. The **Guatemalan kelep**, *Ectatomma tuberculatum* (Olivier) was introduced into Texas in 1904 by the United States Department of Agriculture to control the cotton boll weevil, but failed, according to Wheeler, because it proved to be the wrong species.

Subfamily DORYLINÆ (Haliday 1836) Dalla Torre 1893 (Do-ryl'i-næ, from the Greek *δῶρυ*, spear; from the sting). Driver Ants, Legionary Ants, Visiting Ants, Doryline Ants.

A rather small family of mostly tropical species, some of which occur in the temperate regions of Africa and North and South America. The queens are large, either blind or with vestigial eyes, and apterous. The workers are polymorphic. Head with frontal carinæ close together, almost vertical, and exposing the insertions of the antennæ. Eyes very small or absent; blind queens and workers sometimes found. Mandibles may be greatly developed and long, curved, and toothed. Males winged, wings with or without veins; workers and queens apterous. Abdomen with one- or two-segmented pedicel. Sting vestigial. Genitalia of male may be retractile and are often well developed and complicated. Pupæ naked or in cocoons. These ants are carnivorous chiefly on small insects but may attack small or large mammals and birds. They live in temporary nests and travel on dull days or at night as vast armies in long files. They are said to destroy all animal life that occurs within the line of march. In general they may be said to be beneficial scavengers, but the driver or legionary ants belonging to the genus *Eciton* Latr. of the American tropics have often been portrayed as being most ferocious and devastating to all forms of animal life. The genus *Dorylus* Fab. inhabits the African tropics.

Subfamily DOLICHODERINÆ (Forel 1878) Dalla Torre 1893 (Dol'i-cho-der'i-næ, from the Greek *δολιχός*, long, + *ἔρη*, neck, throat; referring to the slender prothorax). Tapinoma Ants.

The many small ants belonging to this subfamily are commonly known as tapinoma ants, and many species have a characteristic rancid-butter odor. The bodies are smooth, pubescent, or densely hairy. Antennæ 12-segmented; those of the male with the base shorter than the pedicel. Eyes circular or elongate-oval, rather small. Ocelli absent or three present. Epinotum with or without a deep recess and two conspicuous spines. Abdomen with a very small one-segmented pedicel having one inclined scale present or absent; without constriction between segments I and II of the gaster; gaster often carried over the back; cloacal orifice large and slit-like; sting small or vestigial (developed in *Aneuretus*

Emery). These cosmopolitan ants are usually associated with honeydew-producing insects such as aphids, psyllids, aleyrodids, coccids, and other homopterous forms and with the larvæ of the lycanid or blue butterflies. They nest mostly in the ground, but certain species make paper-like carton nests attached to trees, stones, and other objects. The pupæ are naked. Among the important

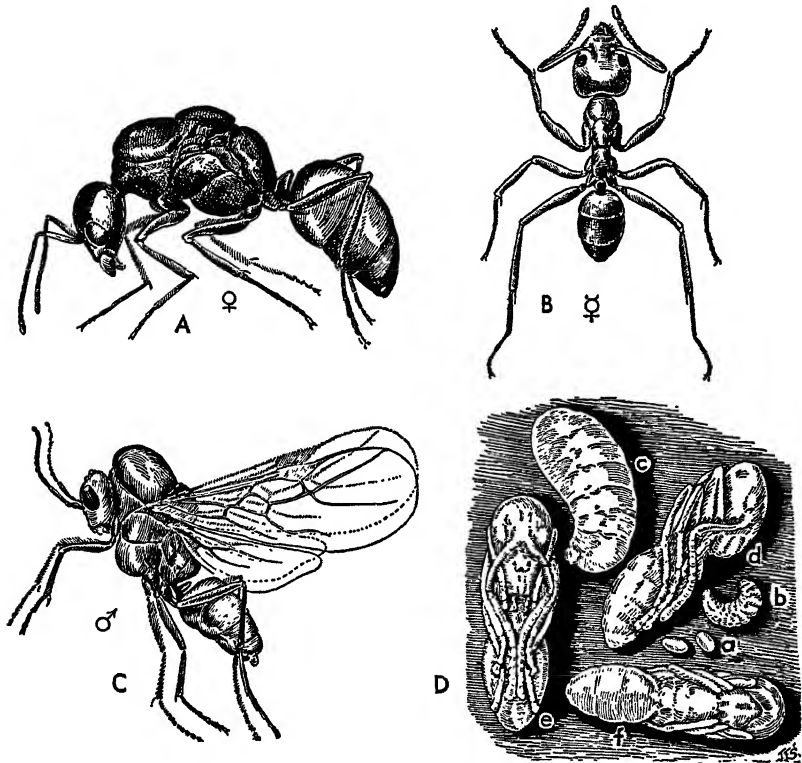


FIG. 235. The Argentine ant, *Iridomyrmex humilis* Mayr, a tropical and subtropical species of North and South America. A, apterous female; B, worker; C, male; D, immature stages, a, eggs; b, young larva; c, fully-developed larva; d, e, f, pupæ. (After Back, U.S. Bur. Ent., 1937.)

genera are *Azteca* Forel, *Dolichoderus* Lund, *Dorymyrmex* Mayr, *Iridomyrmex* Mayr, *Tapinoma* Förster, and *Leptomyrmex* Mayr.

The Argentine ant, *Iridomyrmex humilis* Mayr, a tropical and subtropical species in North and South America, is one of the most annoying house- and garden-visiting species known. It lives in numerous small nests in the soil and marches in more or less definite columns to and from the nests. This genus has 20 representatives in Australia. Of these, *I. detectus* Smith is according to Tillyard the most numerous in individuals of any Australian insect

and constructs large mounds in pathways. It is 8 mm. long and bites painfully. Another Australian species, *I. rufoniger* Lowne, invades houses. The genus *Tapinoma* is represented in Europe by the erratic ant, *T. erraticum* Latr., 2.5–5.0 mm. long, which often walks with raised gaster and spurts an offensive sticky fluid that gums up an intruder. It nests in the ground. The odorous ant, *Tapinoma sessile* (Say), is a very common North American species, nesting under stones and emitting the characteristic tapinoma odor. In the nests of the Australian *Leptomyrmex*, queens have not yet been found (Tillyard, 1926). *L. varians* Emery of Queensland stores honey in repletes. The cocoa ant, *Azteca chartifex* Forel, is inimical to cocoa culture in tropical North and South America because it protects the coccids and other homopterous insects that are injurious to the trees (Wolcott 1933).

Subfamily MYRMICINÆ (Smith 1851) Dalla Torre 1893 (Myr-mic'i-næ, from the Greek *μύρμηξ*, *μύρμηκος*, ant). Agricultural Ants, Harvester Ants, Leaf Cutters, Parasol Ants, Fungus Growers, Myrmicine Ants.

This is one of the largest and most important subfamilies of ants. It is widely distributed throughout the entire world and contains many annoying and in-

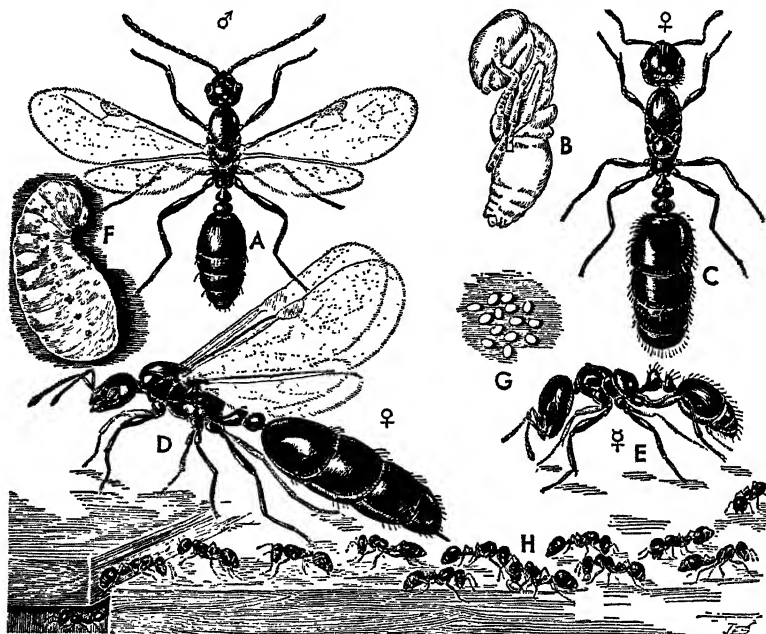


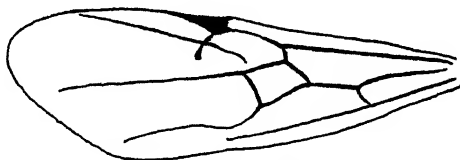
FIG. 236. The little black ant, *Monomorium minimum* Buckley, a common household pest. A, male; B, pupa; C, apterous female; D, alate female; E, worker; F, larva; G, eggs; H, workers marching. (After Marlatt, U.S. Bur. Ent., 1916.)

jurious species, some of which have almost inconceivable numbers of individuals. More than half of the North American species belong to this group. Eyes

usually present, rarely vestigial or absent. Antennæ of males 12-segmented; of queens and workers 11-segmented. Mouth parts normal; clypeus may or may not extend between frontal carinæ; mandibles simple or toothed; small or wide. Tibiæ of middle and hind legs absent or simple. Wings usually present or rarely absent in reproductives; fore pair with one closed cubital cell. Abdomen with distinctly two-segmented pedicel; gaster short; cerci present in males of most genera; male genitalia partly concealed or exerted; sting present. Stridulatory organ present in many genera. Pupæ naked.

These ants are mostly phytophagous and feed upon seeds which they gather and store. Many are fungus growers. These latter, belonging to the neotropical tribe ATTII, cut leaves which they carry to their nests and upon which fungi are cultivated for food. Some eat the tender bark of trees, and others are general feeders that tend aphids, coccids, and lycaenid caterpillars for honeydew, while a few are carnivorous. Many are household pests. Practically all of the following important genera are cosmopolitan: *Anergates* Forel (Palæarctic), *Atta* Fab. (Neotropical), *Cremastogaster* Lund, *Leptothorax* Mayr, *Messor* Forel, *Myrmecina* Curtis, *Myrmica* Latr., *Monomorium* Mayr, *Pheidole* Westwood, *Pogonomyrmex* Mayr, *Solenopsis* Westwood, and *Tetramorium* Mayr.

The social parasitic ant, *Anergates atratulus* Schrank, 2.5–3.0 mm., shares the nests of the turf ant, *Tetramorium cæspitum* (Linn.), 2.5–8 mm., which nests in sandy fields or under stones and makes small mounds. The former rarely has queens, and the males are apterous. Both occur in Europe, and the latter has been introduced into America. Members of the genus *Atta* are variously called "leaf cutters" because they cut leaves and drop them to the ground, "parasol ants" from the fashion of holding the leaves in the air over the bodies while carrying the leaves to the subterranean nests, and "fungus growers" from the culture of fungi on the chewed-up leaves which are mixed with excrement and converted into suitable compost for the growing of hyphæ and the production of swellings or bromata which are eaten by the ants. The hyphæ are carried to new nests by the queens and are characteristic of the species.



Pogonomyrmex

FIG. 237. Wing of the California harvester ant, *Pogonomyrmex californicus* (Buckley).

Members of the genus *Cremastogaster* have various habits, the temperate species frequently nesting in the ground under stones while certain tropical species build globular paper-like nests. *C. scutellaris* Olivier, 3.5–10.0 mm. long, is the commonest European species. The acrobat ant, *C. lineolata* (Say), and its numerous subspecies and varieties occur throughout North America. *Leptothorax emersoni* Wheeler nests close to and connects with the burrows of its host, *Myrmica rubra* (Linn.) subsp. *brevinodis* Emery, the bodies of which it grooms and from which it also steals food as the host workers regurgitate in

feeding others. The red myrmicine ant, *Myrmica rubra* (Linn.), 3–6 mm., has five European subspecies and four North American subspecies and eight varieties. It tends homopterous insects, the larvæ of lycanid butterflies, and is also carnivorous. *M. scabrinodis* Nyal is also well represented by a number of varieties in Europe and North America. The little red, brown, yellow house ant or Pharaoh's ant, *Monomorium pharaonis* (Linn.), 2–4 mm., an Old World species now widely distributed by commerce, is a household pest wherever it occurs and does not come into competition with the Argentine ant. Like most ants, it is said to prey upon termites.

Certain of the fire ants belonging to the genus *Solenopsis* are serious garden and orchard pests. The commonest European species is *S. fugax* Latr., while *S. geminata* Fab. *S. aurea* Wheeler, *S. molesta* Say, and *S. texana* Emery are well known throughout North and South America and are most annoying in tropical areas. The workers are 0.5–2.5 mm. long while the queens are 6–7 mm. in length. They tend mealybugs, and at least one species has been known to strip the living bark from young citrus trees in southern California.

Subfamily FORMICINÆ¹ Ashmead 1901 (For-mi'ci-næ, from the Latin *formica*, an ant). Typical Ants.

This is one of the largest and most important subfamilies of ants. The members are variable in size, ranging from 2–20 mm. in length and averaging

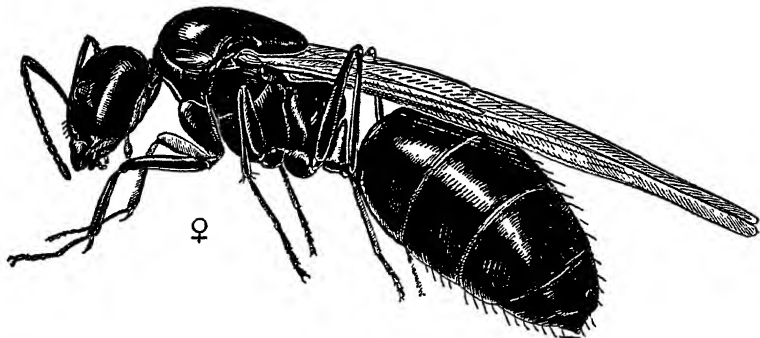


FIG. 238. The herculean carpenter ant, *Camponotus herculeanus pennsylvanicus* DeGeer, a large black species common in eastern North America. (After Back, U.S. Bur. Ent., 1937.)

about 7 mm. Antennae nine- or more-segmented. Mandibles broad and dentate or slender and pointed. Maxillary palpi three- to six-segmented. Abdomen with one-segmented pedicel; without constriction between segments I and II of the gaster; all segments visible from above; anal or cloacal orifice circular, terminal, and surrounded by a fringe of hairs; sting vestigial and nonfunctional; odorous glands absent; male genitalia not retractile. Pupæ usually enclosed in a cocoon, some naked. Workers not conspicuously polymorphic.

The family is widely distributed, and many genera are cosmopolitan, but the

¹CAMPONOTINÆ Forel of authors.

family reaches its highest development in tropical and subtropical regions and is represented by 232 species in Australia and about 70 in North America. The important genera are *Acanthomyops* Mayr, *Camponotus* Mayr, *Formica* Linn., *Lasius* Fab., *Myrmelachista* Roger, *Myrmecocystus* Wesmael, *Polyergus* Latr., *Polyrhachis* Shuckard, and *Prenolepis* Mayr.

To these genera belong some of the most remarkable ants known. Among these the garden or black ant, *Acanthomyops nigra* (Linn.), is the commonest ant in England. It nests in open soil and under stones, builds small mounds, and swarms in great numbers on afternoons in July and August. The herculean ant, *Camponotus herculeanus* (Linn.) (= *ligniperda* Latr.), the largest European ant, is 9–18 mm. in length. It nests in dead wood or under stones, is common and abundant, and invades houses. The subspecies *pennsylvanicus* DeGeer and varieties occur in North America and are abundant in mountain forests. In Australia the sugar ant, *C. nigripes* Smith, is a pest in houses seeking sugar and other sweets, while the black honey ant, *C. inflatus* Lubbock, stores honey in enormously extended repletes.

Members of the genus *Formica* are among the most formidable inhabitants of temperate and cooler regions. The red ant, sanguinary ant or blood red slave maker, *F. sanguinea* Latr., ♂ 7–10 mm., ♀ 9–11 mm., ♀ 6–9 mm., nests in stumps, logs, or in the ground and constructs no mounds. It is a facultative slave maker and raids the nests particularly of *F. fusca* Latr. but also of other ants and takes the pupæ, which become slaves. It is common throughout Europe, and six subspecies occur in North America. The narrow-headed ant, *F. exsecta* Nyal, 5–9 mm. long, builds large mounds of small sticks, coniferous needles, and other debris in the forests of Europe. The common red, wood, hill, or horse ant, *F. rufa* Linn., 9–11 mm., builds huge mounds in the forests of Europe and North America. The pupæ are gathered in quantities and sold as ant eggs for bird food. Three subspecies and seven varieties are listed in North America by Wheeler. The negro ant, *F. fusca* Latr., 5–10 mm., lives in the forests of Europe but seldom builds mounds. Eight varieties are reported in North America.

The dark brown ant, *Lasius niger* Linn., 3–10 mm., and *L. flavus* DeGeer, 2–9 mm., are very common European species that are also represented in North America, the former by three varieties. The variety *americanus* Emery, the commonest of these three varieties in the east and much of the continent, colonizes root aphids on corn, and has been called the cornfield ant. A single subspecies of *L. flavus* DeGeer is found in North America. *Myrmelachista ambigua* Forel var. *ramulorum* Wheeler nests in hollow twigs in the trees shading coffee plantations in the West Indies and rears the mealybug, *Cryptostigma inquilina* Newstead, in the nests along with the young (Wolcott, 1933). The honey pot ants, *Meloporus bagota* Lubbock and *M. cowlei* Froggatt of Australia, and certain species of the genus *Myrmecocystus*

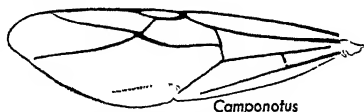


FIG. 239. Wing of the giant carpenter ant, *Camponotus laevigatus* (F. Smith).

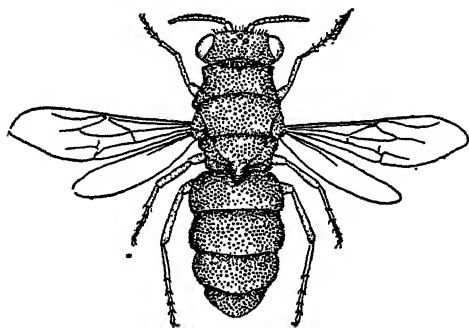
of tropical and subtropical America store honey in repletes. These and other honey ants are eagerly gathered by primitive man as a source of sweets.

The robber ant, *Polyergus rufescens* Latr., 6-10 mm., is an obligatory slave maker, and the workers of various species of *Formica* are essential to make its nests and to rear and feed its young. This European species is represented in North America by three subspecies often referred to as **Amazon ants** in this country. Among the most remarkable of all ants are the red and green tree ants belonging to the genus *Ecophylla* F. Smith which have red, greenish, and black-colored forms that build large nests in trees by sewing the leaves together by the manipulation of web-spinning larvæ as shuttles. The workers are vicious biters and commonly attend aphids, other honeydew-producing homopterous insects, and the caterpillars of lycænid butterflies. The **green tree ant**, *O. virescens* Fab., inhabits tropical Africa, Papua, and Queensland, while the **red tree ant**, *O. smaragdina* Fab., occurs in India.

X. Superfamily CHRYSIDOIDEA Rohwer 1916

87. Family CHRYSIDIDÆ (Latreille 1802) Dahlbom 1854 (Chry-sid'i-dæ, from the Greek χρύσεος, golden; referring to the brilliant metallic colors of these wasps). German, Goldwespen. French, Chrysidés. Gold Wasps, Ruby Wasps, Cuckoo Wasps.

Small to medium-sized, 2-18 mm., slender or stout, brilliant metallic green, red, blue, purple, and other reflections; smooth or coarsely punctured or sculptured; some species when disturbed curl into a rigid position. Head as wide as thorax. Eyes widely separated. Ocelli in a triangle on the vertex. Antennæ setiform, short. Thorax large; scutellum may extend beyond base of abdomen.



Legs slender; claws bifid and with two to six teeth. Wing venation reduced, hind pair of wings with small oval lobe. Abdomen sessile, with two to five (usually three and

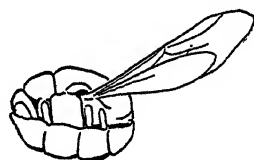


FIG. 240. Edward's cuckoo wasp, *Parnopes edwardsii* Cresson. Right, adult curled in death-feigning attitude. (From *Insects of Western North America*.)

rarely five) dorsal segments visible; venter concave; propodeum with sharp lateral keels or spines; last tergite with apical margins entire, notched, or toothed; ovipositor tubuliferous and retractile. The adults are known as cuckoo wasps from the habit of the females of laying their eggs in the pro-

visioned cells of other insects, particularly of the solitary mud wasps, bees, and other aculeate HYMENOPTERA, while some species are parasitic on LEPIDOPTERA. Step (1932) in referring to the European spiny mason wasp, *Hoplomerus spinipes* (Linn.), states that her instinctive fear is directed mostly against the splendid ruby-tail wasp, *Chrysis viridula* Linn., which will sit patiently for hours watching for an opportunity to get into the nest in order that she may lay her own eggs in the cells of the ever-alert bee. The fat legless larvæ of the cuckoo wasps are chiefly parasitic on the nearly mature larvæ of the hosts, although in some instances they are thought to devour the provisions. They hibernate as larvæ and pupate in a cocoon within the host cells in the spring, the adults emerging in a short time.

The family is a small one and widely distributed throughout the world. The most important genera are *Chrysis* Linn., *Elampus* Spinola, *Hedychrum* Latr., *Notozus* Förster, *Omalus* Dahlbom, and *Parnopes* Fab. One of the finest species is the metallic purple Australian *Stilbum splendidum* Fab. which attains a length of 18 mm. *Omalus punctulatus* Dahlbom of Europe varies from but 2–6 mm.

Members of the related family CLEPTIDÆ Dahlbom 1854 are metallic wasps which are parasitic on the sawflies. In the females the abdomen shows four and in the males five dorsal segments.

XI. Superfamily SPHECOIDEA Ashmead 1899

(Sphe-coi'de-a, from the Greek σφήξ, σφήκος, a wasp.) Thread-waisted and bee-like solitary and colonial wasps.

The members of this superfamily nest singly or in colonies and provision their nests with spiders, grasshoppers, homopterous insects, flies, caterpillars, bees, and other insects and are to be considered beneficial because of the large numbers of destructive species they consume.

LIST OF FAMILIES

- | | |
|--|-----------------------|
| 88. Family AMPULICIDÆ | 92. Family NYSSONIDÆ |
| 89. " EXEIRIDÆ | 93. " NITELIDÆ |
| 90. " STIZIDÆ (ARPACTIDÆ) | 94. " LARRIDÆ |
| 91. " SPHECIIDÆ (from the genus <i>Sphecius</i>) | 95. " PHILANTHIDÆ |
| | 96. " BEMBICIDÆ |
| 97. " PEMPHREDONIDÆ (PSENIDÆ, MIMESIDÆ) | |
| 98. " TRYPOXYLIDÆ (TRYPOXYLONIDÆ) | |
| 99. " SPHECIDÆ (SPHEGIDÆ) (from the genus <i>Sphex</i>) | |
| 100. " CRABRONIDÆ (THYREOPIDÆ) | 105. Family CERCERIDÆ |
| 101. " DIMORPHIDÆ (ASTATIDÆ) | 106. " ALYSONIDÆ |
| 102. " MELLINIDÆ | 107. " MISCOPHIDÆ |
| 103. " GORYTIDÆ | 108. " OXYBELIDÆ |
| 104. " HOPLISIDÆ | |

KEY TO IMPORTANT FAMILIES

1. Prepectal suture originating below margin of prothoracic tubercle; prepectus therefore absent between tubercle and tegula. (Police-man Flies.) **NYSSONIDÆ**
 Prepectal suture originating posterior to prothoracic tubercle; prepectus present between tubercle and tegula 2
 Prepectal suture wanting (Sand Wasps.) **BEMBICIDÆ** p. 686
2. Prepectus defined posteriorly by a strong carina which is angulate opposite prothoracic tubercle; an oblique suture from below tegula to sternum where it joins prepectal carina 3
 Prepectus defined posteriorly by a suture from below tegula to prepectal suture 5
3. Antennæ inserted near middle of face; mesepisternum with a dorsal and ventral plate; abdomen petiolate; wings with three cubital cells. (Aphid Wasps, Pempredon Wasps.) . . . **PEMPHREDONIDÆ** p. 687
 Antennæ inserted very close to dorsal margin of clypeus; mesepisternum without a dorsal plate; abdomen sessile; wings with one cubital cell 4
4. First cubital and first discoidal cells confluent; propodeum with a process at dorsal middle; metanotum with processes at sides; eyes with inner margins subparallel. (Spiny Digger Wasps.)
 **OXYBELIDÆ**
 First cubital and first discoidal cells separate; propodeum and metanotum without process; eyes with their inner margins strongly converging below. (Crabronid Wasps.) **CRABRONIDÆ** p. 689
5. Abdomen with a strong constriction between first and second ventral segments 6
 Abdomen without a constriction between the first and second ventral segments 8
6. Clypeus with a lobe at dorsal middle; antennæ inserted well above clypeus near middle of face; middle tibiz with two apical spurs. (Bee-killer Wasps.) **PHILANTHIDÆ**
 Clypeus with dorsal margin nearly straight; antennæ inserted very close to dorsal margin of clypeus, much below middle of face . . . 7
7. Inner margins of eyes deeply emarginate; middle tibiz with one apical spur. (Mud Daubers and Spider Wasps.) . . . **TRYPOXYLIDÆ**
 Eyes at most reniform, mesal margins subparallel; middle tibiz with two apical spurs. (Sand Digger Wasps.) **MELLINIDÆ**
8. Middle coxæ without a transverse suture near base; propodeum long, with spiracles well removed from base; abdomen with a long petiole; middle tibiz with two apical spurs. (Thread-waisted Wasps, Mud Daubers, Digger Wasps.) **SPHECIDÆ** p. 687
 Middle coxæ with a transverse suture near base; propodeum shorter and with spiracles close to metanotum; abdomen usually sessile but, when petiolate, middle tibiz have but one spur 9
9. Metasternum with a large process which is deeply emarginate ventrally; middle tibiz with one apical spur; wings with three cubital cells; radial cell appendiculate. (Sandloving Wasps.) . . . **LARRIDÆ** p. 685
 Metanotum without large deeply emarginate process 10

10. Abdomen depressed, dorsal surface flattened; middle tibiae with two apical spurs; radial cell truncate; three cubital cells present. (Varicolored Wasps.)

DIMORPHIDÆ

Abdomen cylindrical or in a few cases subdepressed, dorsal surface convex; middle tibiae with one apical spur; venation variable. (Aphid Wasps, Pemphredon Wasps.)

PEMPHREDONIDÆ p. 687

Family LARRIDÆ¹ Stephens 1829
(Larr'i-dæ, etymology obscure).
Sandloving Wasps, Burrowing Wasps.

Small to medium-sized species, 3–23 mm. in length, somewhat robust and bee-like; black or with yellow, golden, or reddish markings; finely or densely pubescent. Head broad; eyes with inner margins parallel or diverging ventrally; ocelli perfect or imperfect and flattened. Pronotum normal or trilobed; metasternum with large deeply emarginate ventral process. Middle tibiae with one apical spur. Wings with cubital cells, the second not petiolate; marginal cell appendiculate. Abdomen petiolate. The nests are usually series of cells in the sand, but some species are thought to make indefinite cells for their young. Tillyard (1926) states that *Tachysphex australis* Saussure of Australia has been observed to break open the mud cells of *Sceliphron latum* Smith and to lay its eggs on the stored spiders of the latter and then seal up the cells. The cells of most species are provisioned with crickets, grasshoppers, mantids, and young bugs. The adults

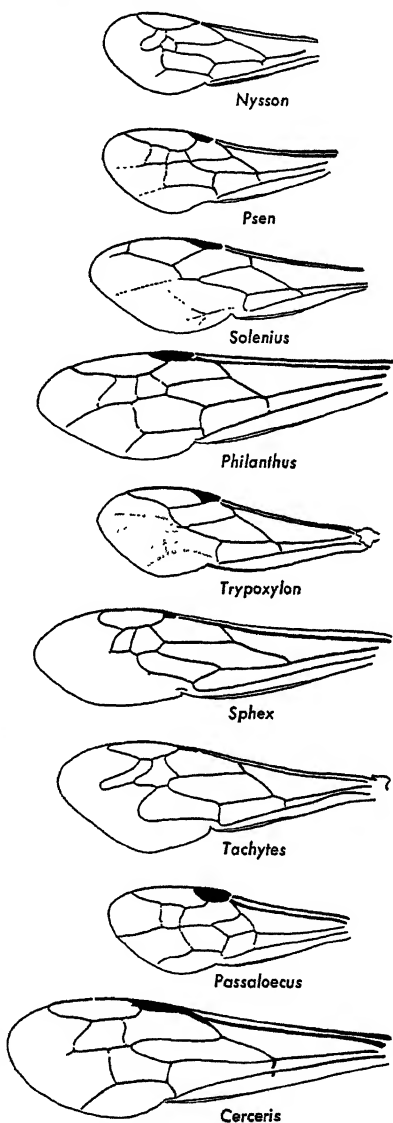


FIG. 241. Wings of sphecoid wasps. All drawn to same scale, except *Nysson* which is enlarged slightly more than the others.

¹ See footnote 2, page 595.

frequent flowers. The most important genera are *Larra* Latr. (cosmopolitan), *Lyroda* Say (Nearctic), *Tachytes* Panzer (cosmopolitan), and *Tachysphex* Kohl (cosmopolitan). The last named is the largest and best known genus. *Larra americana* Saussure, of Brazil, is being employed as a parasite of the mole cricket or changa, *Scapteriscus vicinus* Scudder, in the West Indies.

Family BEMBICIDÆ¹ (Latreille 1702) Stephens 1829 (Bem-bic'i-dæ, from the Greek βέμβιξ, a buzzing insect). Sand Wasps, Bembicid Wasps.

Large and robust species, 14–20 mm. long; smooth or finely pubescent; black or grayish and with greenish, yellow, orange, or red markings and abdominal bands. Head large and transverse; eyes large, naked or hairy, not emarginate, and with the inner margins parallel or convergent; ocelli normal, poorly developed, or vestigial; antennæ inserted close to the clypeus; labrum large and usually much longer than wide, pointed and rostriform; mandibles simple or toothed; maxillary palpi three-, four-, or six-segmented; labial palpi one-, two-, or four-segmented. Prothorax large, transverse; prepectus and notaulices absent; mesepisternum without dorsal plate. Forelegs fossorial and with a fringe of long inner hairs for moving sand; middle tibiæ with one or two spurs or calcaria. Wings large; veins distinct; pterostigma much reduced; radial or marginal cell normal or appendiculate at tip; with two or three closed cubital cells. Abdomen plainly not petiolate; with broad base and tapering to a point posteriorly; segments I and II of same width.

These are common familiar wasps which so industriously build their nests in sunny sandy places and are engaged throughout the day in opening the burrows, feeding the young, and then closing the entrances time after time since

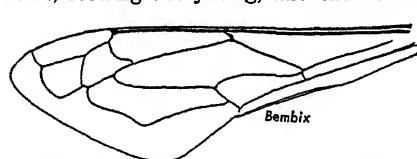


FIG. 242. Wing of the sand wasp, *Bembix beutenmulleri* Fox.

they do not completely provision their cells as do many other wasps.

They are mostly semisocial in that they construct their individual nests in close proximity to those of their neighbors, but some species are quite solitary in habits. The burrows vary from 12 to 24 in. in depth and each

contains five or six larvæ in a single large cell. The young are fed daily, chiefly upon masticated flies, and at least one species is said to serve homopterous insects to its young. When fully grown, the larvæ construct thick oval cocoons in which they hibernate and pupate. The adults issue in the spring and early summer. Like most other insects, the immature forms are subject to a considerable amount of parasitism from flies and parasitic wasps.

The family is more or less cosmopolitan. The largest and best known genus is *Bembix* Fab. Among its many species *B. rostrata* (Linn.) is one of the commonest in Europe, while *B. spinolæ* Lepeletier has become famous in North America through the studies and writing of the Peckhams in Wisconsin. This

¹ Fabricius erected the genus *Bembix* in 1775 and changed the name to *Bembex* in 1777. The former name has priority, and the family name is spelled as given above.

last named species is the most widely distributed member of the family east of the Rocky Mountains. Other important American genera are *Bembidula* Burmeister, *Bicyrtes* Lepeletier, *Microbembex* Patton, *Steniolia* Say, *Stictia* Illiger, and *Stictiella* Parker.

Family PEMPHREDONIDÆ Dahlbom 1835, 1845 (Pem'phre-don'i-dæ, from the Greek *πεμφρηδών*, a wasp). Pemphredon Wasps, Aphid Wasps.

Mostly small wasps ranging from 5–12 mm. in length; wholly black or marked with red, shining or opaque. Head subquadrate or usually transverse; eyes large or small and their inner margins subparallel; antennæ inserted low on the face near the clypeus. Thorax with prepectus present between the prothoracic tubercle and tegula and delimited posteriorly by a distinct carina; metepisternum with dorsal and ventral plate; coxæ of middle legs separated; hind femora without extension. Abdomen petiolate, petiole cylindrical, or trisulcate, and of variable length but usually short. These wasps nest in pithy plant stems, dry grass stems, holes in wood or in the soil, and provision their cells with aphids, psyllids, and other small HOMOPTERA. These hosts are usually killed, but a few may live for some days or weeks. The most important genera are *Pemphredon* Latr., *Psen* Latr., *Psenulus* Kohl, *Stigmus* Panzer, and *Passalæus* Schuckard. *Psenulus atratus* (Fab.), *P. fuscipennis* Dahlbom, and *P. pallipes* Panzer of Europe store aphids in nail holes in wood and in grass stems in thatched roofs. The family is chiefly Holarctic.

Family SPHECIDÆ¹ (Leach 1815) Comstock and Comstock 1895 (Sphec'i-dæ, from the Greek *σφήξ*, *σφηκός*, a wasp). Sphecids, Thread-waisted Wasps, Mud Daubers, Digger Wasps.

Long slender wasps characterized by the stem-like abdominal petiole; usually black or less often metallic blue, purple, or green, and often brightly ornamented with yellow, orange, or red markings; naked or pilose. Head large and transverse; eyes large with inner margins parallel or subparallel; antennæ near middle of face; clypeus long and slender. Thorax slender; prothorax triangular or transverse; prepectus delimited posteriorly by a suture or carina. Legs long and slender; fore pair fossorial; middle tarsi with two apical spurs; middle coxæ without basal transverse suture. Wings slender and with three cubital cells. Abdomen long and slender; propodeum long with spiracles distant from base; petiole shorter or longer than the gaster and may include segments I and II and part of III; gaster cylindrical or depressed in cross section, without a deep constriction between venter of segments I and II.

This is a large cosmopolitan family of wasps whose members construct mud cells singly or in series on rocks, trees, buildings, and other protected places and provision them with spiders, or excavate holes in the ground which they provision with caterpillars and orthopteroid insects. In all cases the cells are closed after provisioning and egg laying. The larvæ pupate within thin reddish-brown

¹ The giant cicada killer, *Sphecius speciosus* (Drury), one of the largest North American wasps, is placed in a separate family SPHECIIDÆ.

parchment-like cocoons. The adults are highly specialized insects that approach intelligence, and in behavior they are among the most interesting of all animals. The studies of the French naturalist Jean Henri Fabre and the Americans George W. and Elizabeth Peckham and Phil and Nellie Rau have done much to popularize many of these wasps whose nesting habits are now being por-

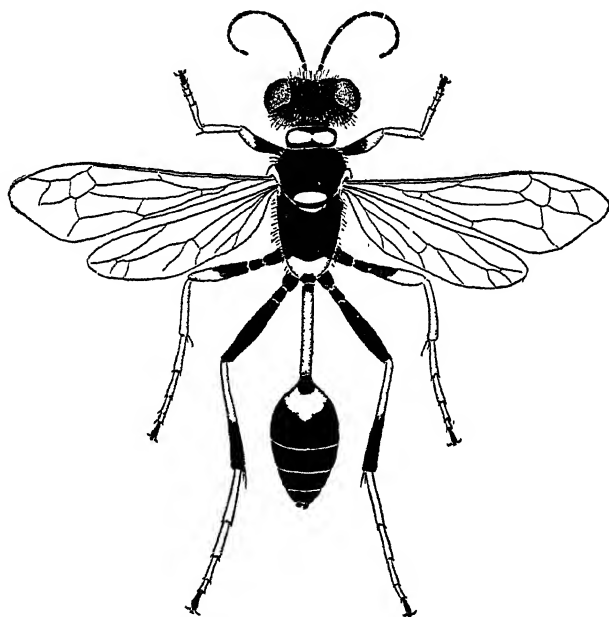


FIG. 243. Yellow and black mud dauber, *Sceliphron servillei* (Lepelletier), a wasp that builds series of mud cells on stones and walls and provisions them with spiders. (From *Insects of Western North America*.)

trayed by motion-picture color photography. These wasps are well represented in subtropical and temperate regions.

The most important genera are *Sphex* Linnæus (*Ammophila* Kirby),¹ *Chlorion* Latreille, *Chalybion* Dahlbom, and *Sceliphron* Klug (*Pelopæus* Latr.).² The species of *Sphex*, investigated by Fabre, include the hairy ammophila, *S. hirsuta* Scopoli; the silky ammophila, *S. holoserica* Fab., and the sand ammophila, *S. sabulosa* Linn. The Peckhams studied *S. unaria* Klug, and the Raus reported on *S. punctipennis* (Walsh). *Sphex vulgaris* Cresson, a very common North American species, has been ably discussed by Howard (1902). The steel-blue mud dauber, *Sphex luctuosa* Smith (*Psammophila*), is another well-known North American wasp.

¹ *Sphex* Linnæus 1758 has priority over *Ammophila* Klug 1801.

² *Sceliphron* Klug 1801 has priority over *Pelopæus* Latr. 1802 which was changed to *Pelopæus* Latr. 1802.

The blue mud wasp, *Chalybion cæruleum* (Linn.), is a beautiful species occurring throughout much of North America. It provisions its mud cells with spiders, chiefly of the genus *Epeira*. Members of the genus *Sceliphron* are mostly black and yellow species from 15-30 mm. in length which store spiders in mud cells on stones and masonry walls. The best known species are *S. destillatorium* Illiger of Europe; *S. cæmentarius* Drury of Boreal North America; *S. servillei* (Lepeletier) of western North America; and *S. latum* Smith of Australia.

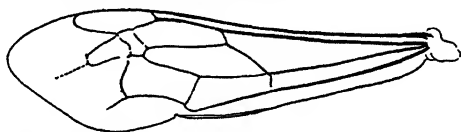


FIG. 244. Wing of the blue mud dauber, *Chlorion cyaneum* (Dahlbom).

Family CRABRONIDÆ (Leach 1815) Dahlbom 1845 (Cra-bron'i-dæ, from the Latin *crabro*, a hornet). Crabronid Wasps, Square-headed Wasps.

Small to medium-sized species varying from 0.64 mm.-17.00 mm. in length; mostly black with yellow, orange, or reddish markings. Integument smooth or often partially sculptured and hairy. Head quadrate or subquadrate, large, being sometimes wider than the body; eyes with inner margins converging towards the mouth; clypeus transverse and usually hirsute; mandibles acute, simple, bidentate, or tridentate. Thorax often about same size as the gaster; mesepimeron with or without a pronounced carina; mesepisternum punctate or strongly sculptured; wings hyaline or fuscous, fore pair with one cubital cell and appendiculate radial cell, hind pair with closed cells. Abdomen sessile, subsessile, or petiolate; propodeum without spine or scales.

These are common wasps that constitute a large family especially abundant in the Holarctic region; some species are cosmopolitan. The members have a wide variety of nesting habits and occupy holes or burrows in the stems of plants, in wood, and rarely in sand banks. The adults provision their young with spiders, mites, aphids, young bugs, caterpillars, and other small insects. Pupation occurs in a thin silken parchment-like cocoon. The most important genus is the cosmopolitan *Crabro* Geoffroy which usually nests in wood and stores flies. *C. 4-cinctus* Fab. is the commonest European species. There are many North American species of which *C. latipes* (Smith) is widely distributed throughout the boreal regions. The genus is divided into no less than nine common subgenera.

XII. Superfamily VESPOIDEA Ashmead 1899

Wasps, Hornets, Yellowjackets, Velvet Ants, Mud Daubers, Mason Wasps.

Medium to large hunting wasps which nest above or below the surface of the ground and for the most part are insectivorous and araneidivorous; both sexes winged or the males winged and the females apterous; antennæ 13-segmented in males and 12-segmented in females; pronotum extends backwards to

the tegulæ; trochanter a single segment; gaster with six visible dorsal segments. These wasps are predators, endoparasites, ectoparasites,inquilines, or pollen and nectar gatherers. The workers are winged and the females have a well-developed and effective sting. The generalized sequence in establishing colonies is, according to Rau and Rau: prey-nest-egg for the psammocharids, and nest-egg-prey for the eumenids and the social forms.

LIST OF FAMILIES

109. Family SAPYGIDÆ	116. Family THYNNIDÆ
110. " RHOPALOSOMATIDÆ	117. " METHOCIDÆ
111. " SIEROLOMORPHIDÆ	118. " MYRMOSIDÆ
112. " MUTILLIDÆ	119. " APTEROGYNIDÆ
113. " ANTHOBOSCIDÆ	120. " EUMENIDÆ
114. " SCOLIIDÆ	121. " STENOASTERIDÆ
115. " TIPHIIDÆ	
122. " PLUMARIIDÆ (KNOWIELLIDÆ, ARCHIHYMEIDÆ)	
123. " PSAMMOCHARIDÆ (POMPILIDÆ, CEROPALIDÆ)	
124. " ZETHIDÆ	129. Family MASARIDÆ
125. " VESPIDÆ	130. " EUPARAGIIDÆ
126. " POLISTIDÆ	131. " GAYELLIDÆ
127. " POLYBIIDÆ	132. " RAPHIGLOSSIDÆ
128. " RHOPALIIDÆ	

KEY TO MOST IMPORTANT FAMILIES

1. Wings distinctly plicated or folded longitudinally 2
 Wings not distinctly plicated or folded longitudinally 3
2. Claws dentate; two forms; females, males EUMENIDÆ p. 695
 Claws simple; three forms; females, workers, males VESPIDÆ p. 698
3. Antennæ distinctly thickened apically and in most species end in a club
 MASARIDÆ p. 701
 Antennæ never ending in a club 4
4. Legs very long, posterior femora when directed backwards extending
 beyond middle of abdomen; mesepisternum with a dividing cephalo-
 caudal suture PSAMMOCHARIDÆ p. 697
 Legs of usual length, posterior femora when directed backwards not
 reaching to middle of abdomen; mesepisternum without a dividing
 cephalocaudal suture 5
5. Sternellum large, sharply defined, extending between intermediate coxæ
 so they are well separated; females winged; tibiæ usually flattened
 with bristles exteriorly SCOLIIDÆ p. 694
 Sternellum not defined; intermediate coxæ contiguous; or, if coxæ are
 somewhat separated, readily distinguished from the preceding family
 by not having sternellum separated from eusternum by a transverse
 suture; tibiæ not flattened and without a single rugose area; if rugose,
 nearly uniformly so 6
6. Clypeus with length and width subequal or nearly so; female winged;

apex of abdomen in male without appendages; eyes deeply emarginate. Parasitic on bees and sphecoid wasps **SAPYGIDÆ**

Clypeus transverse, very much wider than long; apex of the abdomen in male armed or unarmed; eyes usually entire 7

7. Female thorax divided into three parts; apex of abdomen in male armed with a single spine **METHOCIDÆ**

Female thorax divided into two parts, prothorax being well separated; apex of abdomen in male without spines. **MYRMOSIDÆ**

Female thorax undivided; apex of abdomen in male with two spines **MUTILLIDÆ**

Family SAPYGIDÆ (Latreille 1810) Leach 1819 (Sa-py'gi-dæ, from the Greek *σᾶος* or *σῶς*, sound or whole, + *πυγή*, the rump, buttocks; referring to the entirety of the apical abdominal segments). Sapygid Wasps, Parasitic Wasps.

Medium-sized wasps, 8–10 mm. long; black or dusky with white and yellow markings and bands. Eyes deeply emarginate. Clypeus with length and width subequal. Legs short. Wing veins well developed in both sexes; hind pair with a prominent anal lobe. Abdomen not petiolate; the male with a deep constriction between segments I and II; hypopygium of male unarmed; female with a long sting, the base enclosed in a tube.

The adults of this small widely distributed family frequent the nesting sites of wasps and bees and instead of making their own nests areinquilines in those of the wasps **ODYNERIDÆ** and **SPHECIDÆ** and bees of the families **MEGACHILIDÆ**, **XYLOCOPIDÆ**, and possibly others.

Family MUTILLIDÆ (Latreille 1802) Stephens 1829 (Mu-till'i-dæ, from the Latin *mutilus*, maimed, mutilated; referring to the apterous females). German, Bienennameisen, Spinnennameisen. Mutillids, Velvet Ants, Solitary Ants.

Medium-sized, 8–30 mm. long, brightly colored wasps whose males are usually winged and whose females are wholly apterous. In size they vary from the small Indian *Mutilla lilliputiana* André, the female of which is only 3 mm. long, to the large North American cow-killer ant, *Dasymutilla occidentalis* (Linn.), which measures 16–30 mm. in length and occurs throughout southeastern United States. The bodies of both sexes are dark and generally clothed with thick, short or fairly long, white, yellow, golden, orange, or bright-red hairs that are often combined with black hairs; they are rarely naked. Antennæ 12-segmented and curled in the females and 13-segmented and straight in the males. Eyes small, circular or oval, plain or faceted. Ocelli of the males quite large. Mandibles simple or dentate. Thoracic segments closely fused; lateral angles of the pronotum extending to bases of wings. Legs stout; those of female fossorial; middle and hind tibiæ two-spurred. Wings usually present in males, only rarely wanting; venation much reduced; fore wings with one to three closed cubital cells; veins not extending to terminal margins; stigma present; hind wings

without closed cells or anal lobe; cubital cell not originating beyond transverse median vein. Abdomen with or without a short, simple petiole and a deep constriction between segments I and II and II and III; apex of male with one or more spines; female with or without visible sexual organs. Sexual dimorphism is exhibited not only in the absence of wings in the females but also by a difference in colors and in size, the females being usually larger. Females make a squeaking noise by stridulating.

These insects occur in hot semiarid and desert regions, and many species are active during the hottest part of the day while others may appear at nightfall and a few are nocturnal. The females may be found running over the ground. Australian species also occur on the trunks of trees. The males of



FIG. 245. Mutillid wasps or velvet ants. A, *Dasymutilla sackenii* (Cresson); B, *D. gloriosa* (Saussure). (From *Insects of Western North America*.)

certain species visit flowers. They are almost entirely parasitic in the nests of ground-inhabiting bees and wasps, their larvæ preying directly upon the larvæ of the host but not sharing its food. The host list is undoubtedly large, but those most generally observed to be attacked are wasps of the genus *Chalybion* Dahlbom and the bees of the genera *Bombus* Latr. and *Nomia* Latr. Some species are known to parasitize ants, and African species are also reported as preying upon the pupæ of the tsetse flies, *Glossina* Wiedeman.

This large family, numbering more than 3,000 species, occurs mostly in tropical and subtropical regions in Africa, Asia, Australia, North America, and South America.

The most important genera are: *Mutilla* Linn., a large cosmopolitan group; *Dasymutilla* Ashmead, *Photopsis* Blake, and *Sphærophthalma* Blake are American; *Myrmosa* Latr. and *Dasylabris* Radoszkowski are European; *Traumatomutilla* André is South American; and *Ephautomorpha* André, with its 197 species, is Australian.

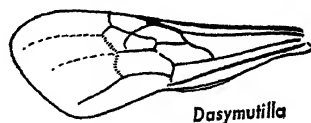
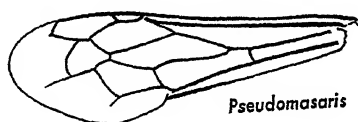
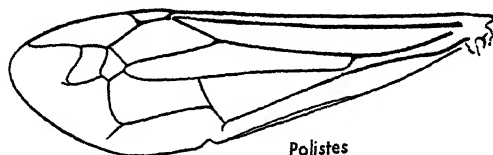
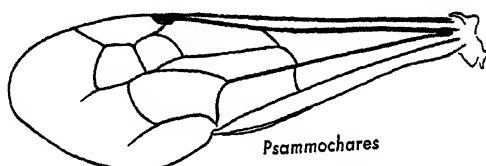
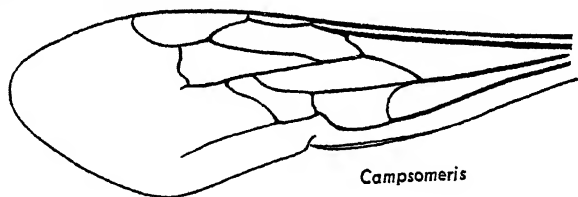


FIG. 246. Wings of vespoid wasps drawn to scale.

Family **SCOLIIDÆ** (Leach 1815) Westwood 1840 (Sco-li'i-dæ, from the Greek σκολιός, curved, bent, crooked; referring perhaps to the bent antenna and leg segments). Scoliid Wasps, Hairy Flower Wasps.

Small to large, mostly densely hairy, black wasps, spotted and banded with white, yellow, orange, or red and some with iridescent reflections. Head somewhat globular, usually narrower than thorax. Antennæ short, bowed or curled. Eyes large, entire or emarginate. Sternum large and distinctly defined. Legs short and strong; tibiæ usually flattened, with long bristles; middle tibiæ with one or two spurs and hind tibiæ two-spurred; claws simple or cleft. Wings usually present in both sexes; venation somewhat reduced, veins not extending to the apical margins; two or three radial cells; hind pair with anal lobe. Abdomen elongated, often banded; segments margined with hairs; deeply constricted between sternites I and II; hypopygium of male armed or unarmed. The adults are hunters and are often found in areas infested with white grubs, for which the females dig into the soil. The grub is paralyzed by stinging, a crude cell is excavated about it, the egg is attached, and the cell is closed. The larvæ of the wasp are ectoparasitic on the host. Other beetle larvæ are also attacked, but only during the last instar. Pupation occurs in the cocoons of the wasps in the soil.

This family includes some of the largest and most magnificent wasps. Among these is the Indian *Scolia porcer* Illiger, 48–54 mm. long and 94–100 mm. wing expanse, black with orange markings and blue-green iridescent wings. *Campsomeris annulata* Fab. was introduced into the United States from China and Japan to prey particularly upon the larvæ of the Japanese beetle, *Popillia japonica* Newman. Important genera include *Scolia* Fab., *Campsomeris* Lepeletier, and *Liacos* Guérin.

Family **TIPHIIDÆ** (Leach 1815) Thunberg 1870 (Tiph-i'i-dæ, from the Greek τῖφη and Latin *tippula*, a kind of insect or water spider). White Grub Parasites, Tiphid Wasps.

Small, slender insects varying from 7–13 mm. in length, mostly black, smooth or sculptured, and clothed with dark or pale hairs. Head roundish, as wide as thorax, and with a slender neck. Eyes circular. Ocelli very small. Antennæ short, straight in male, curled in female. Thorax may be less hairy than the rest of body. Legs relatively short; middle tibiæ with one or two spines; hind tibiæ with two long curved spines. Wings narrow, transparent or infuscated; fore pair with two or three radial cells; stigma distinct though short; first transverse cubitus present or incomplete. Abdomen long and somewhat slender; with short petiole; female with deep constriction between segments I and II (I being considerably narrower than II); male with or without spine at tip. The adults of certain species frequent flowers, especially those of goldenrod and of the family **UMBELLIFERÆ**.

The members of this family are closely related to the **SCOLIIDÆ** and have similar habits in that they mostly parasitize the third-stage larvæ of white grubs. A single female may lay as many as 40 eggs on as many grubs. After she

has paralyzed the host larva by one or more stings and malaxed the ventral surface, she polishes the furrow between segments V and VI and oviposits in the furrow (King and Holloway, 1930). She then nips off or cuts a slit in a foreleg of the helpless grub and feeds upon the exudate.

This family is widely distributed and is most abundant in tropical, subtropical, and warm temperate regions. Certain members are of great economic importance in biological control of white grubs, and a number of species have been introduced into the United States to subjugate the Japanese beetle and other scarabæids. According to Clausen, Gardner, and Sato (1932), species of *Tiphia*, at least, are often host specific to certain species of white grubs. They also oviposit in quite different regions on the body of the grub.

The species of this family have not been carefully studied in North America, but a number have been described, and the host relationships are known. The most important genera are *Tiphia* Fab., *Methoca* Latr., *Elis* Fab., and *Myzine* Latr., all in Europe, and *Tiphia*, *Elis*, and *Paratiphia* Saussure and Sichel, in North America. The most important species introduced into eastern United States (1920-1929) for the control of the Japanese beetle is the Japanese *Tiphia popilliaivora* Rohwer. It has proved to be quite an effective parasite.

Methoca ichneumonides Latr. of Europe is ectoparasitic on the larvæ of tiger beetles.

Family THYNNIDÆ Erickson 1842 (Thyn'ni-dæ, from the Latin *thynnus* and the Greek *θύννος*, the tunny; from their quick, glancing motions). Australian Flower Wasps.

Very remarkable and interesting wasps which reach their greatest development in Australia, where no less than 438 species have been described. They are mostly black but are also often metallic and marked with yellow, orange, and red and measure from 3-25 mm. in length. The males are winged and swift fliers while the females are apterous and run on the ground. In mating, the males of some species grasp the females with their long mandibles and carry them up into the air on a nuptial flight. Dropped to the ground after mating, the females dig into the soil in search of white grubs which are parasitized in much the same way as in the two preceding families. The so-called blue ant, *Diamma bicolor* Westwood, a metallic blue or purple wasp with red legs and antennæ, is a hard stinger. Its females are too large for the males to lift into the air for a nuptial flight. In *Thynnoturneria cerceroides* Smith the males are 8 mm. long and the females only 3 mm.

Family EUMENIDÆ (Leach 1815) Westwood 1840 (Eu-men'i-dæ, from the Greek *εὐμενής*, gracious, kindly, well disposed; referring to their mild dispositions). Potter Wasps, Mud-pot Wasps, Mason Wasps, Mud Daubers.

Medium-sized to large wasps, varying from 9-20 mm. in length. They are dark with white, yellow, orange, or red markings. Antennæ 12-segmented in females and 13-segmented in males. The mandibles are dentate; tongue extend-

ing beyond the mandibles or folded against the sternum. Maxillary palpi three- to six-segmented; middle tibiae with one apical spine; claws dentate. Wings folded longitudinally at rest and often fuscous with violet reflections; fore pair with one radial and four cubital cells. Abdomen has long or short petiole; in some genera the petiole may be longer than the gaster and enlarged posteriorly, while in the genus *Odynerus* Latr. the abdomen appears to be sessile. These are solitary wasps that work in pairs and frequent flowers. They nest in tunnels in the ground, in stems of plants, nail holes, chinks in plaster, burrows in wood, in the deserted nests of bees and wasps, and in beautiful small jugs, urns, or vases

made of mud or clay and attached to twigs. Some species of *Odynerus* build elbowed turrets at the entrances of their burrows which are removed and used to fill up the burrows after they are provisioned. The burrows and cells are chiefly provisioned with from one to 12 caterpillars, but in some cases the larvæ of sawflies and chrysomelid beetles are stored. The eggs may be suspended on a thread from the top of the cell in *Eumenes* Latr.

This large family is widely distributed, attains its greatest development in the temperate regions, and is well represented in Europe, Asia, and North America in the Northern Hemisphere and in Australia in the Southern Hemisphere. It is also plentiful in the Orient.

The Australian *Abispa ephippium* (Fab.), a robust orange and black species, attains a length of 30 mm.

The potter wasps belonging to the genus *Eumenes* Latr. are among the foremost insect artisans and their jug- or vase-like mud cells are exquisitely proportioned.

The heath potter, *Eumenes coarctatus* (Linn.), of Europe, often constructs a group of three or four cells together on a twig. The potter wasp, *E. fraterna* Say, which fills its clay jugs chiefly with cankerworms, is a common species in eastern North America.

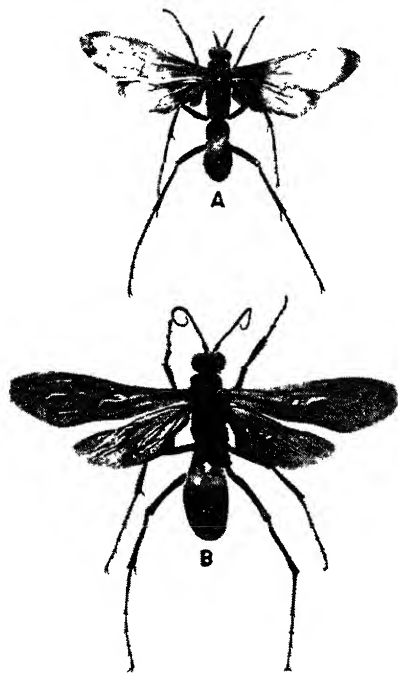


FIG. 247. Tarantula hawks. A, *Pepsis mildei* Stål, male; B, *Pepsis obliquirugosa* Lucas, female. These large wasps provision their nests with trap-door spiders and tarantulas and have a powerful sting. (From *Insects of Western North America*.)

The mason and burrowing wasps of the genus *Odynerus* Latr. normally nest in burrows in the soil, but some species, like *O. birenimaculatus* Saussure of North America, attach to a branch a clay nest the size of a hen's egg and containing many cells and provision it with caterpillars. Rau and Rau (1918) have made some very interesting studies of *O. geminus* Cresson, *O. dorsalis* Fab., *O. foraminatus* Saussure, and other species in Missouri.

The large black *Monobia quadridens* (Linn.), 20 mm. long, of the eastern states nests in wood and partitions the expansive burrows into a series of cells which are provisioned with cutworms (Comstock, 1924). Other genera are *Alastor* Lepeletier, *Gayella* Spinola, *Pterochilus* Klug, *Rhynchium* Spinola, *Synagris* Latr., and *Zethus* Fab.

Family PSAMMOCHARIDÆ¹ Rohwer 1910 (Psam'mo-char'i-dæ, from the Greek ψαμμος, sand, + χαίρω, to take pleasure or delight in; from their preference for sandy nesting sites). Ground Nesting Wasps, Spider Wasps, Spider Hunters.

Small to large wasps, varying in size from the minute *Psammochares mirandus* (Saussure) whose female is but 5 mm. long to the large *P. ilus* Bingham, 27 mm. long. Both of these are Indian species. The adults are very active, black, dark-blue, reddish-brown, or brightly colored with metallic reflections and lighter markings, and some species have dull or brilliant reddish wings. The bodies are smooth, shiny or pilose. Tongue relatively short and extending just beyond the tips of the mandibles. Antennæ usually straight in the males and curled in the females. Prosternum extending back to the bases of the wings. Legs long and slender; tibiae of hind legs two-spurred; claws simple, unidentate, or bidentate. Wings well developed, hyaline, infuscated, or reddish; veins do not extend to the apical margins; fore pair usually with one radial and two or three closed submarginal cells. Abdomen relatively short; pseudopetiolate, the petiole inconspicuous; females with powerful sting. Sexual dimorphism is expressed in smaller males with straight, 13-segmented antennæ and seven visible dorsal abdominal segments whereas the females have 12-segmented antennæ which are usually curled (except in *Ceropales* Latr.), and six visible dorsal abdominal segments. The adults of many species visit flowers.

The red-winged species of *Pepsis* Fab. are among the most interesting and conspicuous members of the family in southwestern North America. The nests consist of burrows in the ground (*Psammochares* Latr.); holes in trees; cracks in mortar, rocks, walls, and buildings; earthen cells (*Agencia* Dahlbom, *Pseudagenzia* Kohl, *Paragenzia* Bingham). They are usually provisioned with spiders, and rarely with crickets, cockroaches, beetles, and other insects.

The genus *Psammochares* Latr. (*Pompilus* Fab.) is the largest and most widely distributed in the family. The blue spider wasp, *P. luctuosus* (Cresson), 10–12 mm. long, stores spiders of the genus *Lycosa* and occurs throughout

¹ POMPILIDÆ Leach 1815, 1819 is relegated to synonymy on the basis of generic priority. *Psammochares* was established in 1796 whereas *Pompilus* Fab. was not erected until 1798. The above name is now generally accepted by most taxonomists.

boreal North America. In California the trapdoor spider wasp, *P. plantus* (Fox), provisions its nests with the large trapdoor spider, *Bothriocyrtum californicum* (Cambridge).

Among the most conspicuous wasps are the tarantula hawks, members of the genus *Pepsis* Fab. They are large species from 20–40 mm. in length, metallic blue-black and with infuscated, violaceous, orange, or fiery-red wings, and they provision their nests with spiders, trapdoor spiders, and tarantulas. *P. elegans* Fab., a rather small species, is the eastern representative of this genus in North

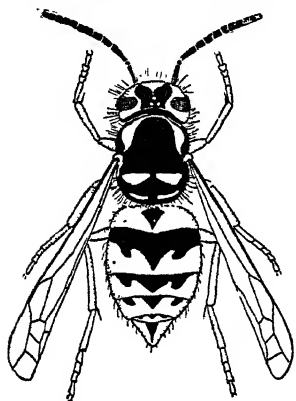


FIG. 248. Worker of the common yellowjacket, *Vespa pennsylvanica* (Saussure), a ground-nesting species. (From *Insects of Western North America*.)

America while a number occur in the south and southwest. In the latter areas *P. formosa* (Say), 20–40 mm., is the commonest and largest species with red wings and *P. obliquerrugosa* Lucas, 30–40 mm., the largest all-blue species. Other genera include the European *Agonia* Dahlbom, *Pseudagonia* Kohl, *Priocnemis* Schiödte; the Indo-Australian *Aporus* Spinola and *Salix* Fab.; and the American and Oriental *Ceropales* Latr. whose members live as inquiline in the nests of species of *Psammochares* and share the food of the host larvæ.

Family VESPIDÆ (Leach 1815) Stephens 1829
(Ves'pi-dæ, from the Latin *vespa*, a wasp).
Paper Wasps, Yellowjackets, Hornets.

Medium-sized to large, mostly slender, smooth, pubescent or hairy, yellow and red with black or brown markings and bands; varying in size from 9–17 mm. Head transverse and as wide as the thorax; clypeus well developed; ocular malar spaces (areas between bases of mandibles and

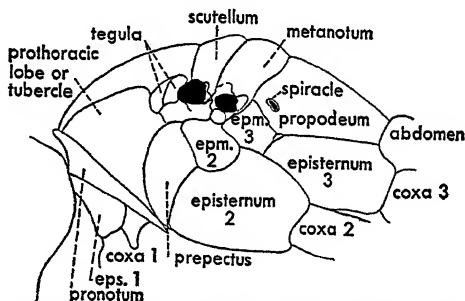


FIG. 249. Thorax of *Polistes aurifer* Saussure showing important parts.

lower margins of eyes) short or long; mandibles strong, dentate. Antennæ fairly long and slender; only slightly bowed. Thorax nearly as wide as abdomen; metepisternum without dorsal anterior plate. Legs strong; middle tibiae two-spurred; claws simple. Wings long and narrow; folded longitudinally in repose; hind pair without anal lobe; veins not extending to the apical margins; fore pair with three submarginal cells. Abdomen sessile, somewhat conical, usually marked with transverse dorsal bands; sting well developed and effective; male genitalia used in separating the family into at least three natural groups.

There are generally three castes; queens or fertile females, workers or sterile females, and drones or males. The males are the product of unfertilized eggs; the queens are fed more and are larger than the workers. Workers may produce eggs which hatch only into males but are incapable of fertilization. The enveloped paper nests are often very large and may be suspended from trees and various other objects or constructed in large holes excavated in the ground. The queen starts the nest in the spring, using wood fiber which is reduced to paper by mastication. When a few cells are completed, a fertile egg is laid in each. The legless white grubs soon appear and are fed daily on insect material and sweets. When the larvæ are mature, the cells are capped and pupation follows therein. Workers only are produced until fall, when the sexes appear and mating occurs. The young queens hibernate and establish new colonies the following spring. The adults feed on various insects, meats, fruits, honeydew, and other sweets, and are often very troublesome about fruit canneries and drying sheds, and also do considerable damage to fresh fruits. This damage is partially offset by the destruction of great numbers of houseflies, stableflies, and other flies, caterpillars, and similar injurious insects. Duncan (1939) has made a splendid contribution to the biology and morphology of the North American vespine wasps.

These common wasps may be separated into three genera according to the width of the malar-ocular spaces and nesting habits as follows:

Malar-ocular spaces either very narrow or absent; nesting above ground, nests suspended from trees and bushes

Dolichovespula (Rohwer)

Malar-ocular spaces well defined; large species nesting above ground in hollow trees, stumps, caves, sheds *Vespa* Linn.

Malar-ocular spaces very broad; nesting underground

Vespula Thomson

Species belonging to the genus *Dolichovespula* (Rohwer) (erected as a subgenus of *Vespula* by Rohwer) include the common European *D. silvestris* (Scopoli) and *D. media* (DeGeer); the European and North American *D. norwegica* (Fab.); the North American *D. arenaria* (Fab.); and the bald-faced hornet, *D. maculata* (Linn.), and *D. adullerina* (du Buysson), an inquiline in the nests of *D. arenaria* var. *fernaldi* (Lewis).

The outstanding representative of the genus *Vespa* Linn. is the giant hornet, *V. crabo* Linn., a European species thought to have been introduced and established in the United States between 1840 and 1854. It was first taken in the United States in 1854. It now occurs in parts of Connecticut, New York, New Jersey, Pennsylvania, Delaware, and Maryland.

Species belonging to *Vespula* Thomson include the well-known European *V. vulgaris* (Linn.); the widely distributed Holarctic *V. austriaca* (Panzner), which lives as an inquiline in the underground nests of *V. rufa* (Linn.); the European and North American *V. germanica* (Fab.) and *V. rufa* (Linn.); and the North American *V. maculifrons* (du Buysson), *V. pennsylvanica* (Saussure), *V. squamosa* (Drury), and *V. sulphurea* (Saussure).

Family POLISTIDÆ (Lepeletier 1836) Gerstæcker 1863 (Po-lis'ti-dæ, from the Greek πολιστής, one who founds a city, founder of a city; referring to their colonies and nests). Polistes Wasps.

Large, slender, long-legged, social wasps which much resemble hornets and yellow jackets in their colorations of yellow, red, white, and black, but differ in their slenderer form and short abdominal petiole. They measure from 9–25

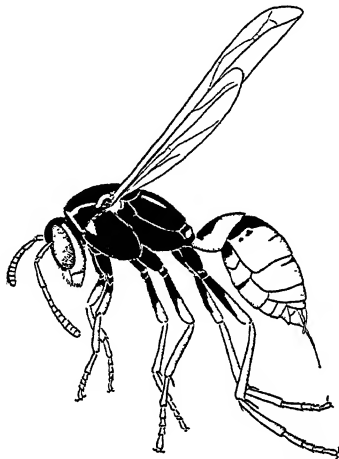


FIG. 250. The golden polistes, *Polistes aurifer* Saussure, a widely-distributed North American wasp that builds its open paper nests beneath the roofs of buildings and in hollow tree trunks. (From *Insects of Western North America*.)

mm. in length. Abdominal segment I, while not stalk-like, is petiolate, and the extensory muscle is inserted in a narrow compressed slit on the propodeum. The adults build small or very large paper nests that consist of a single exposed comb suspended to branches, rocks, underground burrows, hollow trees, under loose bark, and to the rafters of sheds, barns, porches, and dwellings. The adults are hunters and foragers and feed upon insects, especially caterpillars, and on juices of fruits, on honeydew, and on tender plant buds. For their larvæ they capture caterpillars which they malax, *i.e.*, pinch and squeeze, and then crush with their mandibles until the victims are not only killed but macerated and finally removed entire or in bits as food which is supplied daily to the young.

The family is well represented by the genus *Polistes* Latr. which is cosmopolitan in distribution. The common wasp of eastern United States is *P. pallipes* Lepeletier, while *P. annularis* Linn. is also a common eastern and southern species. *P. aurifer* Saussure, *P. bellicosus* Cresson, and *P. texanus* Cresson are common western species. *P. gallicus* Linn. and *P. fæderatus* Kohl are well known in Europe and *P. tepidus* Fab. in Australia. Some very interesting notes on a number of species in the Panama Canal Zone have been published by Rau (1933).

Family **MASARIDÆ** (Latreille 1802) Leach 1817 (Ma-sar'i-dæ, from the Greek *μασάουμι*, to chew; application obscure. Latreille may have believed these to be plant-eating or predacious insects). Masarid Wasps, Shining Wasps.

These medium-sized to large wasps are of interest not only because of their scarcity in collections but also because of their entirely different and knobbed antennæ and the fact that all genera except *Pseudomasaris* (which stores caterpillars) are not insectivorous but provision their cells, made either in mud or in stems, with a mixture of nectar and pollen. Distribution includes North America, South America, Africa, and Australia. The important genera are *Masaris* Fab. and *Celonites* Latr., Palæarctic; *Pseudomasaris* Ashmead, North American; *Masariella* Brauns, *Ceramius* Latr., and *Ceramioides* Saussure, Ethiopian; and *Euparagia* Cresson and *Metaparagia* Meade-Waldo, Australian.

Pseudomasaris vespodides (Cresson), common to western North America, builds mud cells on the sides of rocks.

XIII. Superfamily APOIDEA Ashmead 1899

(A-poi'de-a, from the Latin *apis*, a bee.) German, Bienen. French, Abeilles. Bees.

Small to large, smooth or hairy, dark and brightly colored and often brilliantly metallic insects which are solitary or social in habits and which for the most part store honey, or a mixture of honey or nectar with pollen, or simply pollen as food for the young. All forms are winged. In certain social groups there are three castes: workers or sexually abortive females, queens or true

sexual females, and males. Sexual dimorphism is common, the males usually being smaller than the queens, often holoptic, but not polliniferous or pollen-bearing, and lack a sting. The antennæ are usually 12-segmented in females and 13-segmented in males. The mouth parts of the workers are greatly modified and lengthened for gathering pollen, and the ligulæ and glossæ form a short or long sucking apparatus, commonly referred to as the tongue or proboscis. Pubescence on the head and thorax may be plumose or feathery; the pronotum

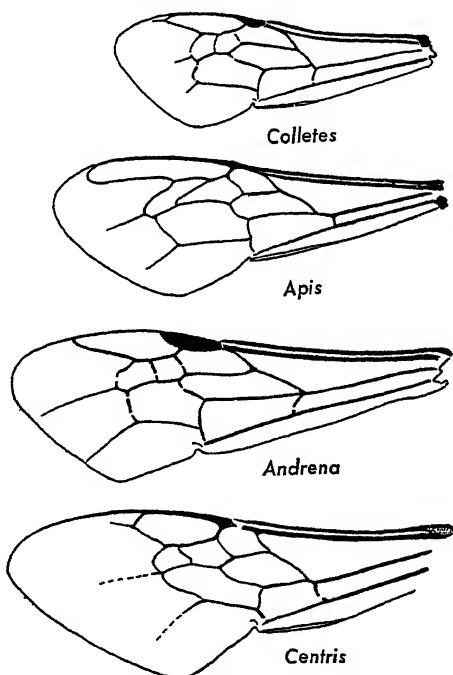


FIG. 251. Wings of bees drawn to scale.

does not extend backwards to the tegulæ; trochanters are undivided; the hind legs of the queens and workers in many species have specializations for collecting and carrying pollen. Larvæ apoidiform: C-shaped, legless, wrinkled, with thin integument and a well-developed though often small head. They feed largely upon nectar or honey, pollen, and a mixture of honey and pollen which is usually stored for their use when needed or is supplied to them regularly from a common source as in the case of the honeybees.

These insects are among the most important and beneficial to agriculture in that they are responsible for the pollination of many crops that are either essential or of great importance to the human race. To collect and transport pollen, bees have developed very interesting and remarkable structures on the hind legs which constitute the so-called pollen basket or corbicula.

LIST OF FAMILIES

- | | |
|--|------------------------|
| 133. Family COLLETIDÆ | |
| 134. " PROSOPIDIDÆ (PROSOPIDÆ, HYLÆIDÆ) | |
| 135. " DUFOUREIDÆ | |
| 136. " MACROPIDIDÆ (MACROPIDÆ) | |
| 137. " HALICTIDÆ (NOMIIDÆ) | 139. Family NOMADIDÆ |
| 138. " ANDRENIDÆ | 140. " MELICTIDÆ |
| 141. " ANTHOPHORIDÆ (PODALIRIIDÆ, EMPHORIDÆ, EUCERIDÆ) | |
| 142. " FIDELIIDÆ | 148. Family MELIPONIDÆ |
| 143. " MEGACHILIDÆ | 149. " PANURGIDÆ |
| 144. " XYLOCOPIDÆ | 150. " EUGLOSSIDÆ |
| 145. " CERATINIDÆ | (CHRYSANTHEDIDÆ) |
| 146. " BOMBIDÆ (BREMIDÆ) | 151. " STELIDIDÆ |
| 147. " APIDÆ | (STELIDÆ) |

KEY TO IMPORTANT FAMILIES¹

1. Tongue short, bilobed; second recurrent vein directed distad before joining subdiscoidal vein. 2
 Tongue elongate, acute; second recurrent vein not bent or directed distad before joining subdiscoidal vein 3
2. Anterior wings with two submarginal cells; pubescence short, sparse; color black with yellow markings PROSOPIDIDÆ p. 704
 Anterior wings with three submarginal cells; pubescence long, dense; color black without yellow markings COLLETIDÆ p. 703
3. Face with distinct subantennal plates; females and some males with impressed, pubescent facial foveæ 4
 Face without subantennal plates; males and females without facial foveæ 5
4. Marginal cell of anterior wing truncate or subtruncate distally, apex separated from wing margin. PANURGIDÆ p. 706
 Marginal cell of anterior wing acute distally, apex lying on margin of wing ANDRENIDÆ p. 705
5. Females and most males with a flat, more or less elevated or produced,

¹ I am indebted to Dr. E. Gorton Linsley and C. D. Michener for the keys to the APOIDEA.

- subtriangular area on apical abdominal tergite; females usually with an anal fimbria or apical fringe of stout hairs 6
- Females and males without a subtriangular area on apical abdominal tergite; females without an apical fimbria 11
6. Clypeus scarcely protuberant, mandibles rarely beveled; labrum concealed except at base and with an elevated basal process; posterior angle of mandible behind posterior margin of eye 7
- Clypeus protuberant or mandibles beveled and exposed labrum: labrum large, without a basal process; posterior angle of mandible anterior to posterior margin of eye 9
7. Labrum smaller than clypeus, not free from mandibles 8
- Labrum larger than clypeus, free from mandibles **DUFOUREIDÆ**
8. Posterior metatarsus equal in width to posterior tibia; basal vein of anterior wing straight or feebly arcuate **MACROPIDIDÆ**
- Posterior metatarsus narrower than posterior tibia; basal vein of anterior wing strongly arcuate **HALICTIDÆ** p. 705
9. Posterior tibiæ of female without a pollen brush; parasitic bees 10
- Posterior tibiæ of female with a pollen brush or scopa; pollen-collecting bees **ANTHOPHORIDÆ** p. 707
10. Anterior wing sculpture highly differentiated, with a broad band of minute papillæ along apical margin, wing hairs mostly along anterior margin; nervellus of posterior wing elongate oblique, often sinuate or curved **MELECTIDÆ** p. 706
- Anterior wing sculpture uniformly distributed; nervellus of posterior wing short, almost right-angled **NOMADIDÆ** p. 706
11. Anterior wings with two submarginal cells 12
- Anterior wings with three submarginal cells 13
12. Abdomen of female with a dense ventral pollen brush, if lacking, tarsal arolia absent **MEGACHILIDÆ** p. 709
- Abdomen of female without a ventral pollen brush; arolia present between tarsal claws **STELIDIDÆ** p. 706
13. Apex of sixth abdominal tergite of female with a spine; solitary bees 14
- Apex of sixth abdominal tergite of female without a spine; social bees 15
14. Anterior wing with first submarginal cell longer than second, as long as third **CERATINIDÆ** p. 711
- Anterior wing with first submarginal cell shorter than second **XYLOCOPIDÆ** p. 710
15. Posterior tibial spurs present **BOMBIDÆ** p. 712
- Posterior tibial spurs absent **APIDÆ** p. 714

Family COLLETIDÆ Bingham 1897 (Col-let'i-dæ, from the Greek *κολλητής*, one who glues; referring to the gelatinous material used to line their sandy burrows in order to retain the fluid provisions stored in the cells).
Colletid Bees, Plumed Bees.

Medium-sized, 6–15 mm., hairy, mostly black and sometimes metallic, solitary bees which somewhat resemble honeybees. Tongue short, broad, and slightly divided at the tip. Antennæ simple, short, 12- to 13-segmented. Ocelli

in nearly straight line across the vertex. Legs short and hairy; with pollen basket; calcaria of hind tibiae equal and half as long as the first tarsal segment; middle tarsal segments wide. Fore wings with one radial and three submarginal cells. Abdomen broadly triangular; segment VI exserted.

These bees nest in sandy or clayey soil or rarely in chinks in mortar and sometimes form large colonies. The burrows are from 8 to 10 in. long, lined with a thin gelatinous and quick-drying fluid, divided into from five to eight cells, one above the other, and are provisioned with a mixture of pollen and honey. The adults visit many kinds of flowers and are of considerable economic importance as pollinizers. The family is a relatively small one, represented in many parts of the world, but it appears to reach its greatest development in Australia, where there are 137 species, mostly belonging to the genus *Paracolletes* Smith. The genus *Colletes* Latr. is the commonest in the Holarctic region.

Family PROSOPIDIDÆ¹ (Dalla Torre 1895) Rayment 1935 (Pro'so-pid'i-dæ, from the Greek προσωπίς, προσωπίδος, mask; because of the fanciful resemblance of their faces to human faces). Yellow-faced Bees, Obtuse-tongued Bees.

Small slender bees, 3.5–8.0 mm.; polished or with little pubescence; mostly black with the faces, particularly of the males, marked with white or yellow.

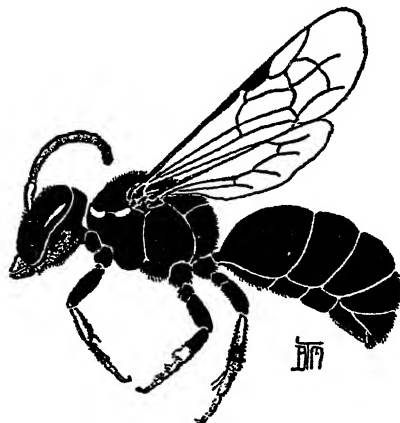


FIG. 252. An obtuse-tongued bee, *Prosopis conspicua* Metz. (After Woodworth from *Insects of Western North America*.)

They are considered to be primitive members of the superfamily and have the mouth parts only slightly specialized. Tongue short and broad, except in the males of certain genera. Legs without pollen-collecting mechanisms. Wings with two submarginal cells. Abdomen of males with special developments on the ventral plates of segments VII and VIII which are of taxonomic value in separating species.

This is a small family of bees with few genera but a large number of species which have a cosmopolitan distribution. They nest in pithy stems, in holes in the ground, or in chinks in walls in buildings. Their cells are lined with a quick-drying

translucent fluid which retains the liquid mixture of honey and pollen. The adults emit a characteristic odor. They are of some value as pollinizers of plants. The most important genus is *Prosopis* Fab. (*Hylæus* Fab.)

¹ The name HYLÆIDÆ is frequently used for this family based on the fact that the genus *Hylæus* Fab. 1793 antedates *Prosopis* Fab. 1804. This family name was first employed by Viereck in 1916. In view of the fact that the Royal Entomological Society of London has petitioned the International Commission of Zoölogical Nomenclature to reject the name *Hylæus*, it has seemed wise to retain the more generally used family name, PROSOPIDIDÆ (PROSOPIDÆ).

Family HALICTIDÆ (Ashmead 1899) Robertson 1904 (Ha-lic'ti-dæ, from the Greek αλιξω, to gather, collect; in reference to the gathering of nectar and pollen). Sweat Bees, Flower Bees.

Small to medium-sized, 5–16 mm., smooth, hirsute, striate or punctured; usually black with yellow or red markings and sometimes with metallic blue, purple, green, brass, or copper reflections. Ocelli arranged in a curve on the vertex, large in certain crepuscular and nocturnal species. Tongue acute, short, straight. Females equipped with well-developed mechanism for collecting pollen. Wings with radial cell pointed apically and three submarginal cells present. Abdomen large, narrower and longer in the male. These bees are especially interesting because of their nesting habits which approach those of the social forms in that *Halictus* Latr. and other genera construct a common burrow and entrance from which individual females make side galleries and cells. They often live in large communities nesting in the ground and provision their cells with nectar and pollen. The members of the genus *Sphecodes* Latr. are shiny black and red species which are social parasites in the nests of *Halictus*. Most of these bees, even including the males of *Sphecodes*, collect nectar and pollen from flowers and are therefore valuable pollinizers and beneficial, especially in crosspollinating fruit trees. Some species are noted for visiting flowers in the evening and even during the night (Stevens, 1926).

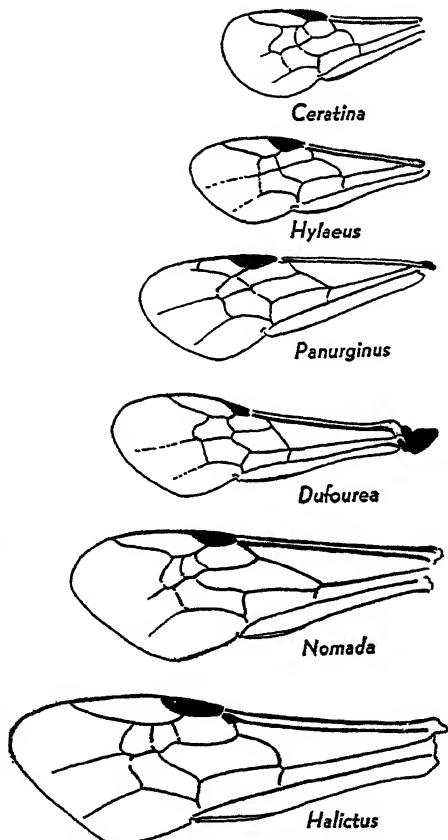


FIG. 253. Wings of bees drawn to scale.

Family ANDRENIDÆ (Latreille 1802) Samouelle 1819 (An-dren'i-dæ, from the Greek ανθρήνη, a hornet, wasp). Andrenid Bees, Short-tongued Burrowing Bees, Mining Bees.

These are small to medium-sized bees, ranging from 5–18 mm. in length, mostly metallic black, marked with yellow or red, some reddish or brownish, and

somewhat resembling the honeybees; the glossa or tongue is shorter than the mentum and there is dense pubescence on the head and thorax. The hind legs are equipped with a pollen-gathering apparatus on the enlarged mid-tarsal segments; hind tibiae are two-spurred; fore wings have two or three cells. They are solitary or colonial in habits, the individual females constructing their own burrows and cells in the ground and provisioning the latter with nectar and pollen.



FIG. 254. An acute-tongued or burrowing bee of the genus *Andrena*. (After Woodworth from *Insects of Western North America*.)

Their colonies are often very extensive and may include many thousand nests. There are one or two broods a year and both sexes remain in the nests throughout the late summer and winter and emerge in the spring. Pupæ may also survive the winter. Sexual dimorphism is expressed in differences of coloration, the males often having yellow faces. Stylopization, which often occurs among these bees, causes marked changes in their appearance and produces a reversal of normal sexual colorations.

This is a large cosmopolitan family, reaching its highest development in the Holarctic region and but poorly represented in Australia. The adults are of

great value to agriculture because of their pollen- and nectar-gathering and their fertilization or pollination of plants. Some species are rather restricted in the flowers they visit. They are particularly fond of the pollen and nectar of plants belonging to the great families CRUCIFERÆ, COMPOSITÆ, ROSACEÆ, LEGUMINOSÆ, and UMBELLIFERÆ, but visit the plants of many other families.

The hairy-legged mining bee, *Dasygaster hirtipes* (Fab.), 10 mm. long, dark with an abundance of long yellow and orange pile, is one of the most beautiful European species and a valuable pollinizer of plants. It nests in sandy places along the coast of southern England and sinks vertical shafts one to two feet deep at the bottom of which two to five cells are excavated and provisioned with pollen paste.

The members of the genus *Andrena* Fab. are abundant in Europe and North America and are among the commonest bees in the fields, meadows, and brushlands. *Andrena miserabilis flavoclypeata* Smith, *A. nasoni* Robertson, *A. winkleyi* Viereck, *A. vicina* Smith, *A. forbesi* Robertson, *A. weedi* Viereck, *A. hippos* Robertson, and *A. bradleyi* Viereck are all important pollinizers of fruits and berries in eastern North America.

The families NOMADIDÆ (Fallén 1813) Kirby 1837, MELECTIDÆ Schmiedeknecht 1882, and STELIDIDÆ (Schenk 1859), Schmied. 1882 are parasites orinquilines in the nests of other bees. The members of the family PANURGIDÆ Schmied. 1882 are pollen and nectar gatherers, resembling members of the ANDRENIDÆ in habits.

Family ANTHOPHORIDÆ¹ Kirby 1837 (An'tho-phor'i-dæ, from the Greek *ἀνθοφόρος*, flowery; in reference to their flower-visiting habits). Anthophorid Bees, Potter Flower Bees, Digger Bees, Hairy Flower Bees, Hairy-footed Bees.

This is a large family of stout, solitary bees intermediate in size between honeybees and bumblebees. They are of variable colors but often yellowish,

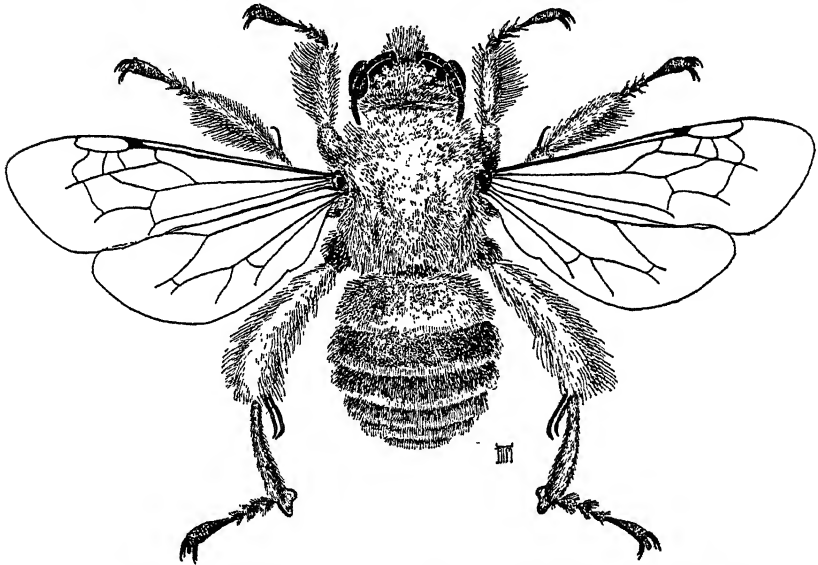


FIG. 255. The anthophorid bee, *Diadasia californica* Timberlake, male. (Redrawn and corrected after Woodworth.)

gray, brown, or black, sometimes with metallic gold, blue, green, and copper colors or iridescences and clothed with thick pile. Head transverse and narrower than thorax. Ocelli distinct. Antennæ short. Clypeus convex and much produced. Tongue greatly elongated; maxillary palpi six-segmented; labial palpi four-segmented. Legs short, strigilis well developed; tibiae and basal tarsal segments densely hairy or pubescent. Middle tarsi of males of some species with long hairs that project in different directions; hind legs of females with widened metatarsus and often orange-colored hairs forming a small corbicula or pollen basket; tibiae two-spurred. Wings hyaline or clouded; fore pair with three sub-marginal cells and with broad appendiculate radial cell. Abdomen broad, wholly pubescent or with transverse pubescent fascia.

These bees usually nest in sand or clay banks and often live in large colonies. The cells are sometimes lined with a clay paste so that they will retain the fluid

¹ A proposal is now before the International Commission of Zoölogical Nomenclature recommending that the name *Anthophora* Latreille 1803, be accepted and the name *Podalirius* Latreille 1802, be rejected (Richards 1937). Favorable action on the part of the Commission will ensure the retention of the former generic and the above family names.

mixture of honey and pollen stored as food for the larvæ. The European *Anthophora parietina* Fab. nests in overhanging banks and its burrows are furnished with elbowed entrance tubes. Some species nest in rotten wood. The family is cosmopolitan in distribution, and the members are of great value in pollinating flowers, especially those with deep corollas in the families BORAGINACEÆ, LABIATÆ, SCROPHULARIACEÆ, VERBENACEÆ, and SOLANACEÆ, and also the COMPOSITÆ. Many species are restricted to flowers of certain other groups.

The most important genus is *Anthophora* Latr. (*Podalirius* Latr.). *Anthophora retusa* Linn., a black species 13–15 mm. long, is a common European

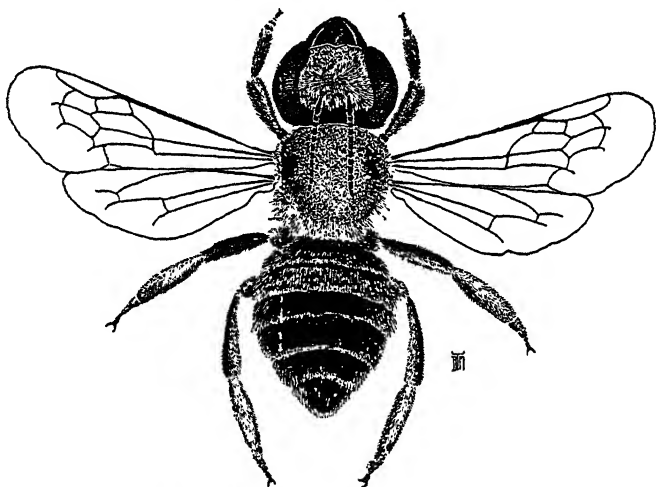


FIG. 256. The leafcutting bee, *Megachile latimanus* Say, an important factor in pollinating alfalfa and clover in western North America. (After Woodworth from *Insects of Western North America*.)

representative while *A. abrupta* Say, 12–15 mm., a black species with pale hairs on the sides and first abdominal segment, occurs in eastern North America; *A. occidentalis* Cresson, 18–20 mm., a large handsome species, black with reddish-brown pubescence, inhabits the Great Plains areas; and *A. urbana* Cresson, 10–13 mm., is the commonest western species. *A. clielligera* Friese, 20 mm. long, is a large African species. The interesting blue-banded bees of the Orient and Australia belong to this genus and the high-pitched “red-singers” of Australia to the genus *Asaropoda* Cockerell. Other common genera are *Centris* Fab. (*Hemisia* Klug), *Eucera* Scopoli, *Melitturga* Latr., and *Tetrapedia* Klug.

Among the many interesting enemies of anthophorid bees in North America are the beetles belonging to the genus *Hornia* Riley, family MELOIDÆ. The mature wingless females, somewhat resembling gravid queen termites, oviposit in the bees’ nest in which they were reared. The active primary larvæ seek the surface of the soil, attach themselves to nest-building bees, and are carried into the new cells where they destroy the eggs and consume the stored pollen.

Family MEGACHILIDÆ (Latreille 1802) Kirby 1837 (Meg'a-chil'i-dæ, from the Greek μέγας, big, great, long, + χεῖλος, a lip; referring to the large labrum). German, Bauchsammler, Blattschneiderbienen. Leafcutting Bees, Megachilid Bees.

Mostly medium to large, solitary hairy species somewhat resembling honeybees but usually more robust and darker in color, generally black or metallic dark blue, purple, or green, and many clothed with white, tawny, yellow, brown, or reddish pubescence and hairs. Head large, often as wide as the thorax. Antennæ geniculate and short. Ocelli in a triangle. Mouth parts well developed; labrum very large; tongue long and slender. Mandibles stout, long, sharp, or expanded apically, and often toothed. Scutellum large. Legs long and hairy; coxæ of some males toothed; without pollen-gathering apparatus. Wings ample and with two large submarginal cells. Abdomen strongly sessile; females with pollen brushes which may be brightly colored on several ventral segments (absent in *Calioxys*, *Lithurgus*, and other inquilines); apical segments of males notched and sometimes toothed in males of *Megachile*.

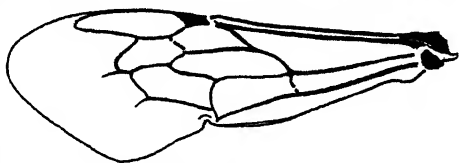


FIG. 257. Wing of the magachilid bee, *Osmia quadriceps* Cresson.

The members of this large family of cosmopolitan bees have a wide diversity of habits. The nests (*Megachile*) are made in burrows in rotten wood or in holes in solid wood, in hollow plant stems, in mortar, or in the soil. The cells are lined with ovals and circles cut from the leaves of roses and many other plants, the ovals being used for the sides and the circles for partitions. The cells are arranged end to end in series of from 10 to 12, provisioned with nectar-pollen paste, and a single egg is deposited on the food in each cell. The pollen is carried by means of brushes on the undersides of the abdomen. The sharp mandibles work like scissors to cut out disks from the leaves in a remarkably short time. Certain species may line the cells with thistle-down, cotton coma, or other plant fibers. The mason bees of this family build their cells of clay while in France the so-called "resiners" employ plant resins in their construction.

One of the smallest members of the family is *Ashmeadiella microsoma* Ckll. of western North America which measures only 3.5 mm., and one of the largest is the Indian *Megachile monticola* Smith, which is 26–27 mm. in length.

Many of these bees, especially *Megachile* Latr., *Osmia* Panzer, *Ashmeadiella* Cockerell, *Anthidium* Fab., and *Dianthidium* Ckll., are valuable pollinizers of plants, and in areas of western North America certain species of these are the chief agents in cross-fertilizing alfalfa for the production of seed. The members of the genera *Dioxys* Lepeletier, *Calioxys* Latr., and *Lithurgus* Latr. are inquilines or parasites in the nests of *Anthophora* Latr., *Chalicodoma* Lep., *Megachile*, and probably other bees. The age-old wall bee, *Chalicodoma muraria* (Retzius), of southern Europe and northern Africa, constructs a series of eight or nine cells of masonry completely plastered over, hemispherical in shape, and

about the size of half a baseball. These are attached often in colonies to stones, walls, and similar exposed places. They have been carefully studied and described by the great French naturalist, Jean Henri Fabre.

Family XYLOCOPIDÆ (Lepelletier 1841) Shuckard 1859 (Xy'lo-cop'i-dæ, from the Greek ξύλον, wood, + κόπτω, to cut; referring to their wood-boring habits). Carpenter Bees, Wood Bees, Xylocopids.

Middle-sized to large, usually thickly haired, robust bees; black or metallic dark blue or green and some with whitish or yellow pile, rarely yellow like the yellow carpenter bee, *Xylocopa æstuans* (Linn.), of India, or the females dark and the males partly or wholly buff or yellowish as in the California carpenter bee, *X. californica* Cresson, and other species. Head transverse.

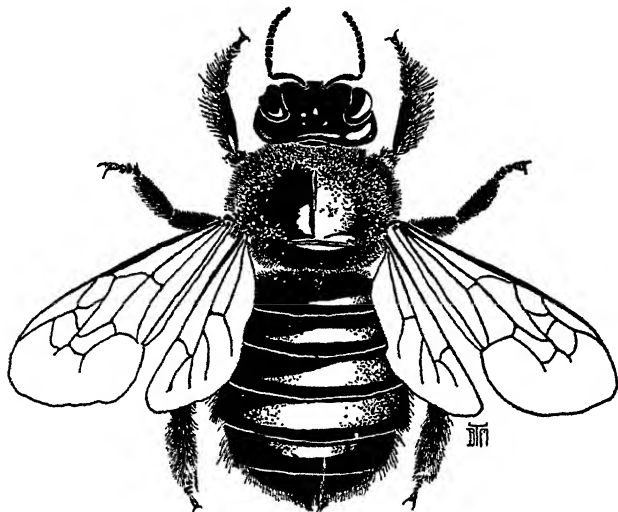


FIG. 258. A carpenter bee, *Xylocopa varipuncta* Patton. The females are black and the males buff-colored. (After Woodworth from *Insects of Western North America*.)

Antennæ geniculate and relatively small. Mandibles with two or three teeth. Labrum short or long, with large free part and protuberances. Eyes larger and closer together in male than in female. Ocelli in a triangle; large in nocturnal species. Tongue long. Legs stout and very hairy; fore and middle tibiae one-spurred, hind tibiae two-spurred, densely hairy; hind metatarsus widened and very hairy; pollen-collecting apparatus absent. Wings long and narrow; frequently infuscated and iridescent; with elongate radial cell and three submarginal cells. Abdomen large, sessile; sometimes with long keel or truncate; an acarid chamber on ventral base of segment I in the African genus *Mesotrichia* Westwood (*Koptiorthosoma* Gribodo) is inhabited by a comparatively large parasitic mite, *Paragreenia* Cockerell.

These remarkable bees somewhat resemble bumblebees but are less hairy

and more flattened and are said to be the largest of bees, varying in length from the small Indian *Xylocopa iridipennis* Lepeletier, 13–17 mm., to the magnificent Indian *X. latipes* (Drury), a black species, the males having the fore tibiae and tarsi yellow and ornamented with long yellow hairs; females, 32–35 mm. They nest in dry wood or rarely in hollow stems, and some species are more or less specific in choosing a particular kind of wood. The burrows are often quite large and may be a foot or more in length. The cells are provisioned with honey-pollen supplied with a single egg and partitioned off, one above the other. Their borings in fence posts and structural timbers may result in considerable damage. In *Xylocopa* the males can be distinguished by the 13-segmented antennae, a single apical spine on the hind tibiae, seven exposed abdominal segments, and two teeth at the apex of the mandibles whereas the females have 12-segmented antennae, two apical spines on the hind tibiae, six exposed abdominal segments, and two teeth at the apex and two on the upper margins of the mandibles.

The adults may hibernate in the cells. There are diurnal and nocturnal species which visit many kinds of flowers.

These bees are restricted to a few genera and to about 350 species, being widely distributed throughout the forested areas of the warmer regions and attaining their greatest development in the tropics where more than 300 species are known to occur. There are but three species in Central Europe, 26 in North America, three in Australia, and 18 in British India. The two most important genera are *Xylocopa* Latr., widely distributed in tropical and warmer temperate regions of the world, and *Mesotrichia* Westwood, limited to Africa and chiefly to its tropical areas. The commonest European species is *Xylocopa violacea* (Linn.), 14–16 mm., while in eastern and southern North America the great carpenter bee, *X. virginica* (Drury), 20–25 mm., is the most abundant species. The beautiful large dark-reddish and golden *X. rufescens* Smith is a nocturnal species whose loud hum and buzzing is heard on moonlight nights in Burma.

Family CERATINIDÆ¹ (Latreille 1802) Ashmead 1899 (Cer'a-tin'i-dæ, from the Greek *κεράτιον*, diminutive for *κέρας*, a horn; referring to the short antennae). Ceratinid Bees, Small Carpenter Bees.

Small bees, 3–12 mm. long, usually sparsely haired; dark or with blue, purple, or green metallic colors. Antennae short, somewhat clavate. Tongue long; mandibles strong and tridentate. Legs short and strong; without special pollen-collecting apparatus. Wings clear or somewhat dusky; stigma well developed; radial cell rounded apically; with two or three submarginal cells. Abdomen slightly narrowed basally; segment VI exerted. They are solitary bees, nesting in the hollow stems of reeds and other plants or in small twigs from which the pith is removed to make a series of cells that are provisioned with nectar-pollen and partitioned with pith or plant fiber. An egg is laid in each cell, and the

¹ The genus *Clavicera* Latr. (April, 1802) has priority over *Ceratina* Latr. (May–July, 1802), but a petition now before the International Commission of Zoological Nomenclature seeks to set aside and avoid the former name.

hatching and maturity begins at the bottom, the adults eating through the partition immediately above and awaiting the emergence of the top and last member in order to escape together with the mother which may await the young in the space outside the cell. Some species utilize the burrows for another brood, there being two life cycles a year. The adults of the later brood hibernate in the cells and emerge the following spring. The members are beneficial pollinators of plants. The family is a rather small though widely distributed one. The

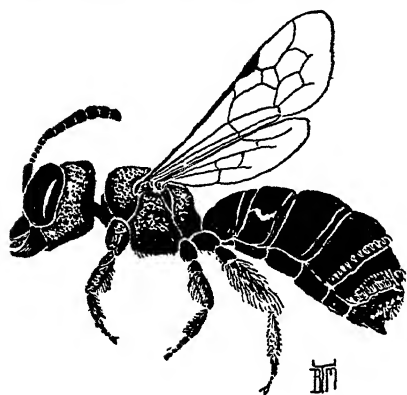


FIG. 259. A small carpenter bee, *Ceratina acantha* Provancher. (After Woodworth from *Insects of Western North America*.)

most important genera are *Ceratina* Latr. (*Clavicera* Latr.), *Allodape* Latr., and *Exoneura* Smith.

Family BOMBIDÆ¹ (Lepeletier 1836) Kirby 1837 (Bom'bi-dæ, from the Greek βόμβος, a buzzing or humming; referring to their loud buzzing sounds in flight). German, Hummeln. French, Bourdons. Humblebees, Bumblebees, Carder Bees.

The bumblebees are among the most interesting of all bees and, next to the honeybees, are perhaps best known to the layman. Their industry is phenomenal, and they perform

their tasks with the ardor and efficiency of well-trained artisans. They are medium-sized to large, 9-30 mm., robust, densely hairy, varicolored with black, white, bright yellow, orange, or red pile. Head narrower than the thorax. Eyes rather elongate. Ocelli nearly in a straight line on vertex. Antennæ geniculate and longer in the males. Tongue long and pubescent; mandibles large, the apices rounded and notched. Legs slender in males and stout in the females. In the females the hind tibiae are wide and flat, two-spurred, smooth. The exterior is densely fringed with long hairs. The first tarsal segment is oblong with a large apical tooth and its margins and inner surface beset with short stiff hairs all of which are combined to form a large corbicula or pollen basket. Wings long, with three subequal submarginal cells, the second of which is characteristically curved and pointed basally. They are social, living in large, well-organized colonies of three castes: sexually developed females or queens which are very large; sexually abortive females or workers which are variable in size and often quite small; and males which are intermediate to the queens and workers.

The large fertilized queens hibernate in hollow trees, refuse, or in the ground,

¹ The genus *Bremus* Panzer 1801 antedates *Bombus* Latr. 1802 and therefore has priority. But because of the long use and extensive literature associated with the latter name, the International Commission on Zoological Nomenclature has been petitioned to suppress the name *Bremus* Panzer and to retain *Bombus* Latr. Should this petition be denied, *Bremus* and BREMIDÆ must be used.

and appear in the spring. They seek a suitable nesting place in a deserted rodent's hole or make one for themselves and start the new colony by gathering pollen and nectar and storing it in the nest. When sufficient food has been accumulated, eggs are laid on the paste-like mass and the white legless larvæ soon appear and feed throughout the paste, no cells being provided for the young by the queen. While these first larvæ are developing, the mother continues to provision the nest and to lay eggs. Soon the very much smaller workers begin to appear and there is new life about the nest. They enlarge the

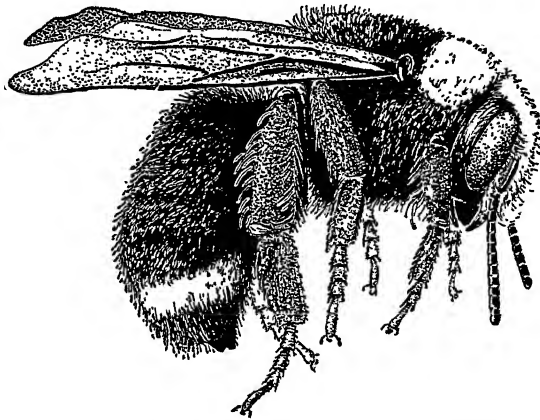


FIG. 260. Worker of the western yellow-faced bumblebee, *Bombus vosnesenskii* (Radokowsky), a common western species first collected by the Russian entomologist Vosnesensky in California in 1841. (From *Insects of Western North America*.)

burrow, gather food, and construct brood cells, thus relieving the queen of all duties except egg laying. So the nest soon becomes a large community occupying a deep or shallow hole from 8 to 12 in. in diameter, lined with straw or bits of dry plants, and with one or more entrances. The cells are mostly for the brood, each cell containing from one to several larvæ, but some are stored with pollen and others with honey. There may be large and small workers, but none of them equal in size the large hibernating queens. Sexes appear in the fall and mate. The males and workers gradually perish with the approach of winter, and the fertile females or queens seek hibernating quarters under the bark or in some old burrow or hollow tree.

Because of their very long tongues, bumblebees are able to pollinate clovers, alfalfa, and many other blossoms which ordinary bees cannot reach, and are of great value in the production of seed in a number of such crops. It is impossible to grow certain varieties of red clover where bumblebees or other long-tongued bees do not exist. Respecting their introduction into New Zealand, Tillyard (1925) calls attention to the fact that four species: *Bombus hortorum* (Linn.), *B. lucorum* (Linn.), *B. ruderatus* (Fab.), and *B. terrestris* (Linn.) were introduced from Europe to pollinate red clover, also previously introduced, "but the

commonest of these, *B. terrestris* L., does not possess a tongue long enough to do this. These bees have gained the objectionable habit of cutting directly into the ovaries of certain flowers to get the nectar, and do considerable damage to broad beans." Though often introduced into Australia, they have not become established there (Rayment 1935).

Often occupying the same nests and resembling their hosts are the so-called false bumblebees belonging to the genus *Psithyrus* Lepeletier which areinquilines and parasites. These bees gather no food but invade the nests of bumblebees, often killing the queen and substituting their eggs for those of the host. The bumblebee workers supply cells and food and rear the parasites without any apparent knowledge of the situation.

Bumblebees are widely distributed throughout the Holarctic region and also occur in the high mountains of the tropics. As every country boy knows, the workers carry a powerful sting which they can use in a most effective manner.

Family APIDÆ¹ (Latreille 1802, Leach 1815) Samouelle 1819 (Ap'i-dæ, from the Latin *apis*, a bee). Honeybees.

This family includes the well-known honeybees which are among mankind's most valuable domesticated animals and have been associated with the human race for more than 4,000 years. The members vary in size from the dwarf bee, *Apis florea* Fab., 8-13 mm. long, to the large wild Indian honeybee, *A. dorsata* Fab., the workers of which are 16-18 mm., the males 17 mm., and the queens 18-21 mm. in length. The adults are mostly black or various shades of brown and tan, and are densely hairy. Head as wide as the thorax; eyes ovate, hairy; ocelli in triangle on vertex. Clypeus elongated; tongue long; maxillary palpi one-segmented; labial palpi four-segmented. Wings long and narrow; fore wings with narrow radial cell and three submarginal cells. Legs stout; fore and middle tibiae each with apical spine, posterior tibiae smooth, flattened, and margins fringed with long hairs which form the sides of the corbicula; first segment of hind tarsi broad, fringed with long hairs, and with rows of short stiff hairs on the inside. Abdomen truncate, suboval, usually less hairy than rest of body; segment VI exserted; with a well-developed curved and barbed sting.

These insects build extensive combs consisting of wax cells. The combs are suspended or built into hollow trees, caves, holes in walls or rocks, buildings, and in hives constructed for that purpose. Cells are made in sizes to accommodate the larvæ and pupæ of the different castes and for storage of honey and pollen used for food. The larvæ are fed daily and when mature cap their cells with a silken web.

The adults may consist of sexual females or queens, sexual males or drones, and sexually abortive females or workers. The workers constitute most of the individual members of a colony, which may consist of many thousand bees. They do all the work in preparing living quarters, building combs, gathering

¹ Some of the designations of this important family have been APIARIÆ, APES Latreille 1802; APIDA Leach 1815; APIDÆ Samouelle 1819; APIARIDES Lepeletier 1841; APINA Thomson 1869; APIDÆ Comstock and Comstock 1895, Ashmead 1899, Robertson 1904, and most authors since then.

and preparing food, feeding the young, and defending the colony. They secrete the wax from abdominal glands and also gather resins which are utilized in the nest in various ways. Colonies may continue year after year in a given nest and new colonies are formed by swarming; *i.e.*, a queen accompanied by workers leaves the parent nest and establishes a new colony in a separate location.

These nectar- and pollen-gathering bees are of great economic importance, not only because of the commercial production of wax and honey but even more

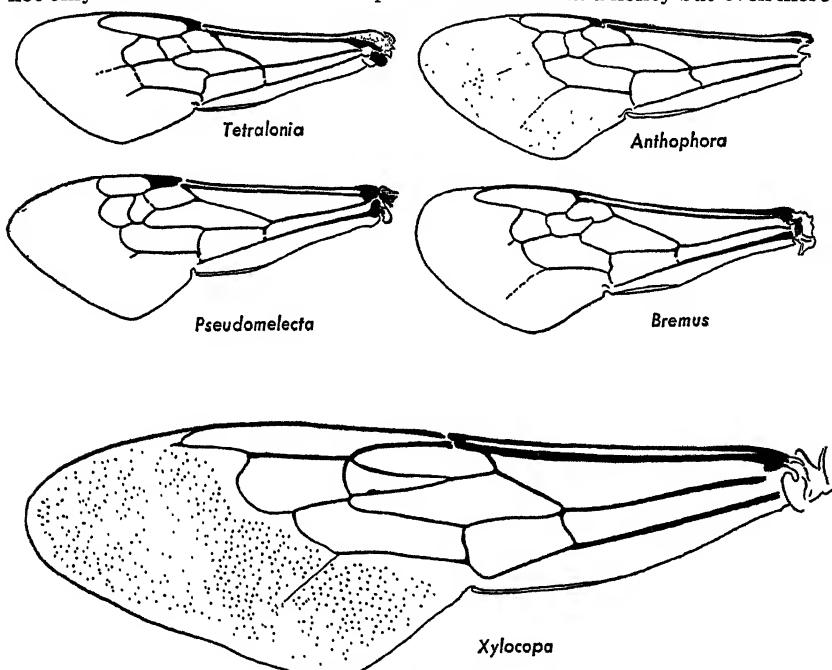


FIG. 261. Wings of bees drawn to scale.

because of the pollination of many agricultural crops which would be totally unproductive without this means of cross-fertilization.

The members of this family belong to the genus *Apis* Linn. Of these the honeybee or hivebee, *Apis mellifera* Linn. (*A. mellifica* Linn.),¹ is not only the most important and best known insect in the order but is the most historical and publicized insect known. Adult members of this species may be divided into three castes: queens or fertilized females, workers or infertile females, and

¹ Linnæus named the honeybee *Apis mellifera* in *Systema Naturæ*, Ed. 10, 1758, but in 1761 (*Fauna Suecica*, Ed. 2) he changed the name to *Apis mellifica*. This latter name has been used almost exclusively since the change was made. In 1894 Dalla Torre (*Catalogus Hymenopterorum*, IX: 595-610) gave the correct synonymy of this important insect. Again in 1904 Benton (*Proc. Ent. Soc. Wash.* VI: 71-73) called attention to the fact that *mellifera* and not *mellifica* was the designation of this insect according to the exacting laws of priority. Certain modern authorities, Bingham (1897), Viereck (1916), Tillyard (1926), Brues and Melander (1932), and Rayment (1935), have used the name *mellifera*.

drones or males. The queens are elongated, 15-20 mm.; drones, robust, 15-17 mm.; workers, 11-15 mm.; mostly various shades of brown and black; the head, antennæ, legs, and portion of the abdomen dark; body clothed with dense short buff or pale pile which is thickest on the thorax and thinnest on the dorsum of the abdomen. This highly social insect lives in large colonies of from 20,000 to 50,000 individuals and has been somewhat domesticated. Wild swarms occur in practically all places where bees are kept.

RACES

There are many races. The four most important ones used in America are characterized as follows:

<i>Races</i>	<i>Color of abdomen</i>	<i>Disposition</i>	<i>Production</i>	<i>Color of cappings</i>	<i>Remarks</i>
ITALIAN	Variable. Dark or with from three to five yellow bands.	Gentle.	Very best.	Nearly white.	Most popular in America. Build few queen cells. Do not run over comb. Keep out wax moth. Most resistant to European foul brood.
CAUCASIAN	Black, gray, or with yellow bands.	Gentlest. Hybrids are cross.	Good.	White.	Used to some extent in America. Use large amounts of propolis. Dark queens hard to distinguish. Very susceptible to European foul brood.
CARNIOLAN	Gray to blackish. Abdominal segments margined posteriorly with white hairs.	Gentle.	Good.	White.	Losing ground in America. Swarm excessively. Build numerous queen cells. Claimed to be resistant to European foul brood.
GERMAN	Black.	Cross, but respond to smoke.	Poor to medium.	White.	Condemned by best American beekeepers. Less prolific than Italians. Run badly over combs and do not keep hives clean. Do not keep out wax moth. Very susceptible to European foul brood.

None of the above races is really resistant to the American foul brood.

CASTES

Queen — fertile female, mother of colony, which arises from fertile eggs and larvæ furnished with special food known as royal jelly; has sting which is used only to kill rival queens.

Workers — abortive or neuter females which arise from fertile eggs; home-makers of the colony; sting used in defense of the colony.

Drones — sexual males, which arise from unfertilized eggs; mate with queens; have no sting.

COMB

The comb consists of two layers of six-sided cells constructed of wax, back to back, and slanting towards the middle partition. The wax is obtained from special glands on the undersides of the abdomen and is masticated and mixed with cephalic gland fluids. It is necessary for the workers to consume 20 pounds of honey to produce a pound of wax. Propolis, a brownish resinous cement collected most abundantly in late summer and fall from buds and trees, is used on rough surfaces, small cracks in the hive, and on portions of the comb.

Honey comb — the cells which are used for storage of honey, usually around the top and sides of the comb. They are capped with wax.

Brood comb — cells which occupy the lower and central portions and consist of the following kinds:

(1) *Worker* — cells similar in size to those used for the storage of honey, containing various stages from the fertilized egg to emerging adult. The mature larvæ spin a thin parchment-like cocoon within the cells where pupation takes place.

(2) *Queen* — very large irregularly shaped cells somewhat resembling a small peanut in shape and size and with the opening downward. The number of queen cells in the brood comb depends upon the season, the race, and the necessity for the same.

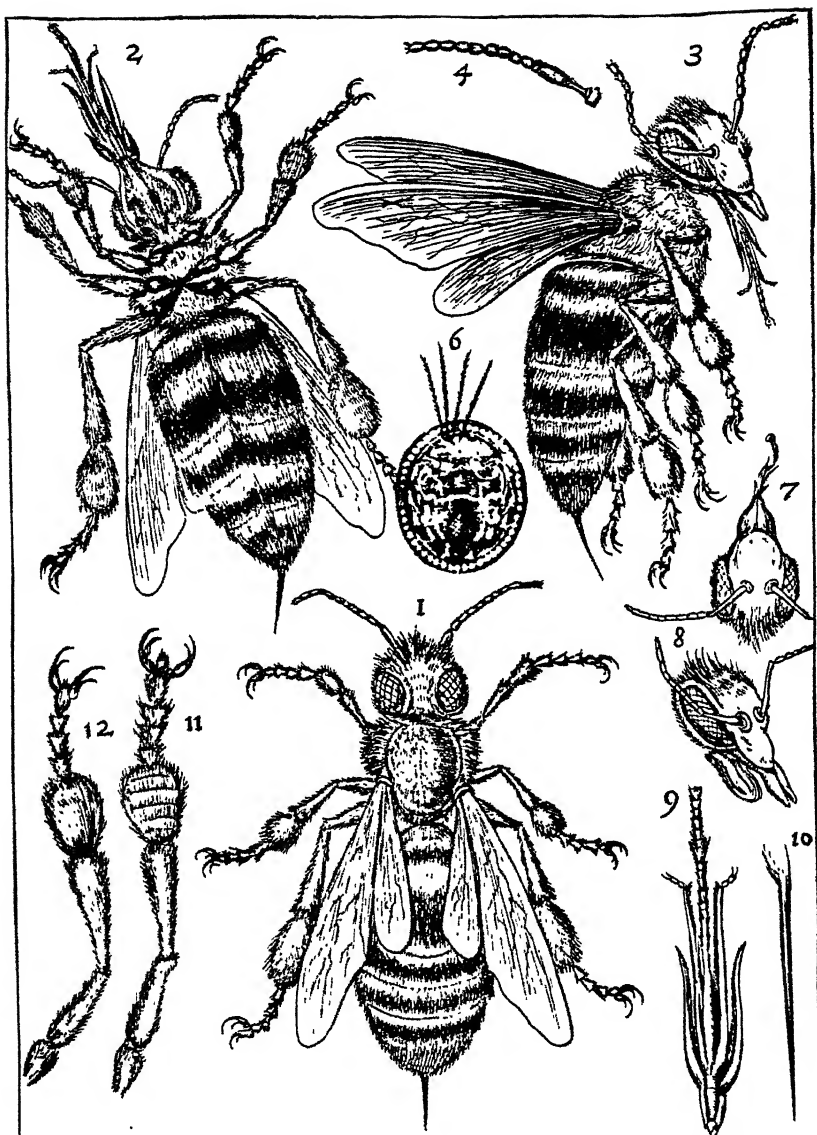
(3) *Drone* — cells similar in shape, of the same size or larger in diameter than the worker cells and somewhat longer. Larvæ hatch from unfertilized eggs.

FOOD

The worker larvæ are first fed on certain fluids from the mouths of the nurse workers and later on a mixture of honey and pollen and on water. The larvæ destined to become queens are given throughout the larval period a thin highly specialized type of food not furnished the others, except during the first 2 or 3 days.

Honey — nectar gathered from plants and elaborated in the honey sac of the workers. It is also made from the honeydew of insects. It is mixed with a small percentage of pollen and is stored as food for the adults, to be used chiefly during the winter or in time of need.

Bee bread — pollen gathered from the flowers of plants mixed with a little honey. It is used for feeding the young.



1. Ape in atto di camminare.
 2. Ape supino
 3. Ape che mostra il fianco
 4. Corno.
 5. Penne dell'Ape
 6. Ochio tutto peloso

7. Testa cō tutte le sue parti.
 8. Testa con la lingua ripie-
 gata verso la gola
 9. Lingua con le sue
 4 linguette, o guaine
 che l'abbracciano

10. Aculeo, ouero Spina
 11. Gamba che mostra la
 parte interiore.
 12. Gamba dalla banda
 esteriore

FIG. 262. This remarkable early drawing of the honeybee is thought to be the first illustra-

Water — collected directly or extracted from the nectar and used for feeding young and adults.

Royal jelly — a highly nutritious material which is secreted mostly by young adult workers and fed to all very young larvæ. It constitutes the entire food of the larvæ destined to become queens.

LIFE HISTORY

Duration of stages — these vary somewhat with temperatures (after Loch-head).

	<i>Egg</i> *	<i>Larva</i> *	<i>Pupa</i> *	<i>Total</i> *
Queen	3	5½	7	15½
Drone	3	6	15	24
Worker	3	5	13	21

* Days.

Swarming — a departure from the old colony, all of the reasons for which are unknown. Among other reasons, however, is the desire to relieve overcrowding and to establish new colonies. This departure usually consists of the old queen and a large following of drones and workers; may occur from none to many times in a season; usually in late spring and early summer and after a new queen and drones appear. A new queen remaining in the old colony stings to death any other young rivals and, after a nuptial mating flight in midair, returns to the hive and continues the egg laying for the colony.

Mating — occurs in spring, summer, or fall in midair during the nuptial flight of the queen. The spermatheca is filled with spermatozoa from the male, there being sufficient to fertilize all the eggs subsequently laid to produce workers and queen. Queens usually mate but once. Drones may or may not be killed by the workers after mating or in the late fall or when food is scarce.

ECONOMIC VALUE

Aside from production of honey and wax, which is of great value in many parts of the world, the honeybee is probably of greatest importance to agriculture in the pollination of plants. The benefits thus derived are so far-reaching as to be impossible of estimation. In many of the orchards farmers and beekeepers are coöperating in the use of honeybees to cross-pollinate the blossoms of fruit trees. Many varieties of these trees cannot be profitably fertilized in any other manner, and other apparently self-fertilizing varieties are very greatly benefited by the work of the bees. For this purpose one stand of bees is recommended for each acre of mature orchard trees.

tion of an insect or object of nature made with the aid of a lens. Items which indicate the use of an instrument of magnification are: (4), ring segments of antenna; (5), plumed body hairs; (6), hairy and faceted eye; (9), and details of the mouth parts and (11), the pollen basket. The original was prepared by Frederico Cesi (1585-1630) and appeared in a work entitled "Apiarium" which was printed by the first Academia dei Lincei at Rome in 1625. The figures were also printed later by Francesco Stelluti in an Italian translation of the poems of Persius in Rome in 1630. (After Bodenheimer, 1929.)

The wild honeybees of the Orient include the giant Indian bee, *Apis dorsata* Fab., already mentioned, which occurs in India, Ceylon, Java, and China and builds a huge single comb up to three or six ft. long and attaches it to rocks, trees, and buildings. This bee is very pugnacious and a severe stinger. The oriental hive bee, *A. indica* Fab., of India, Ceylon, and Malaysia, according to Bingham (1897), "merges into the common *A. mellifera* Linn., the honey-bee *par excellence* of Europe." The dwarf bee, *A. floræ* Fab., the smallest species of the genus, 8–13 mm. long, has a distribution similar to that of the preceding species.

Family MELIPONIDÆ (Ashmead 1900) Schwarz 1938 (Mel'i-pon'i-dæ, from the Greek μέλι, honey, + πόνος, work, toil; *i.e.*, honey gatherers). Stingless Bees, Mosquito Bees, Dammar Bees.

Minute to small, black, brownish, or yellowish bees varying from the minute *Trigona minima* Gribodo, 2 mm., of Central and South America, to *Melipona interrupta* subspecies *grandis* (Guérin), 12–15 mm., of tropical South America.

The adults resemble small honeybees and form a natural group commonly known as stingless bees because of the poorly developed and useless stings. Head transverse with broad front; eyes narrow and extending below bases of mandibles; ocelli in straight line on vertex. Antennæ with filiform flagellum. Thorax somewhat globular; pronotum depressed. Legs stout; posterior tibiae broad and flattened with fringes of hairs forming a corbicular; hind tarsi flattened. Wings slender; veins reduced; stigma small or conspicuous. Abdomen usually short and oval or pointed; the males and workers secrete wax from the tergites.

Like their near relatives, the honeybees, they are social, live in small or large colonies, gather pollen and nectar, and build combs of horizontal layers, one above the other, consisting of like or different sizes of cells for the brood, pollen, and honey. The eggs are laid on the food in the cells after the latter are fully provisioned, and the larvæ are supplied with an adequate amount of food for their development and are not fed daily as in the case of the honeybees. Their nests are built in holes in trees, rocks, or banks or against walls; and are entered by means of funnel-shaped tubes. In the genus *Trigona* Jurine of the Orient the nest is constructed of cerumen or a mixture of wax and plant oils and resins. Concerning this nest-building material in India, Bingham (1897, p. 56) states: "The resinous product collected and used by these bees in making their nests is called 'Pwe'-nyet' by the Burmese, and after boiling in water and mixing with earth-oil or petroleum is largely used for the caulking of boats. The right of collecting 'pwe'-nyet' is sold by the local government in Burma and Tenasserim yearly and forms one of the sources of revenue under Minor Forest Products."

The family consists of three genera and about 300 species and subspecies which are distributed throughout the tropical regions of the world. The two important genera are *Trigona* Jurine, relatively small species 2–8 mm. long, which are further characterized by long wings extending beyond the tip of the abdomen and distinct stigma; and *Melipona* Illiger, relatively large species,

7-9 mm. or longer with the wings not extending beyond the tip of the abdomen and a weak stigma. *Melipona fasciata* subspecies *paraënsis* variety *guerreroënsis* Schwarz 1936 is the domestic stingless bee of Central Mexico which Usinger (1935) found producing a fine grade of white honey much used by the natives in the district of Temascaltepec. *Trigona pallida* (Latr.), a light-yellow bee, is widely distributed in the tropics of North and South America while the karbi, *T. carbonaria* Smith, only 4 mm. long, is the commonest species in Australia.

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CHAPTER XXXV

32. Order DIPTERA ¹ Linnæus 1758

(Dip'ter-a, from the Greek δι, *dis*, twice, + πτερά, wings; referring to the single pair of wings.) German, Zweiflügler.
French, Diptères.

Flies, Gnats, Midges, Mosquitoes, Punkies

Minute to medium-sized, diurnal, crepuscular and nocturnal, terrestrial and aquatic insects with sucking and lapping, piercing, or vestigial mouth parts; complex metamorphosis; thin, fragile, parchment-like integument. Head hypognathous, attached by slender neck. Antennæ variable, simple or with arista. Eyes large, separate or contiguous, rarely divided. Ocelli, usually three present. Fore wings developed for flight, with few veins. Hind wings represented by a pair of halteres (rarely absent) or small vestigial organs. Rarely brachypterous, apterous, or with vestigial wings. Legs short or very long; tarsi five-segmented; one pair of claws, pulvilli, and an empodium usually present. Larvæ dipteroid, usually cylindrical or spindle-shaped; segmented; with or most often without head; mouth parts inconspicuous; eyes usually absent; apodous.

Flies are a group of homogenous insects for the most part and are readily distinguished by the single pair of wings and the characteristic form of the body and its more or less distinct type of appendages, particularly the antennæ, mouth parts, legs, and by their movements on foot and on the wing. The adults are among man's greatest tormentors, ever-persistent nuisances, and his most effective enemies as carriers of innumerable agencies of disease and death. Although no other order of insects affects the human race so adversely, many large families do much good in the reduction of carrion and in the destruction of phytophagous insects that destroy agricultural crops. A few species have even been used for food.

Flies are among the swiftest and most agile fliers and can outmaneuver any other insect on the wing. Regardless of exaggerated claims, certain species can probably travel 50 miles an hour which is a real accomplishment for such small, light, and fragile bodies. While many species are more or less noiseless in the air, most members of the group are decidedly noisy and hum with a soft or loud, low or high-pitched tune which is somewhat characteristic of the families, and may serve in locating the opposite sex in mating. In contrast to the swift flights of the hunting parasitic flies are the lazy gyrations of the common house-fly in the living room and the leisurely or lively so-called mating dances of so many gnats and dance flies. Some forms like the syrphid flies, big-eyed flies, horn flies, and hippelates flies hover in the air above or about the contemplated host. The members of the African genera *Aenigmatias* Meinert and *Aenigmatistes* Shelford have neither wings nor halteres. Others are very active and

¹ The manuscript of this order was read and augmented by T. H. G. Aitken.

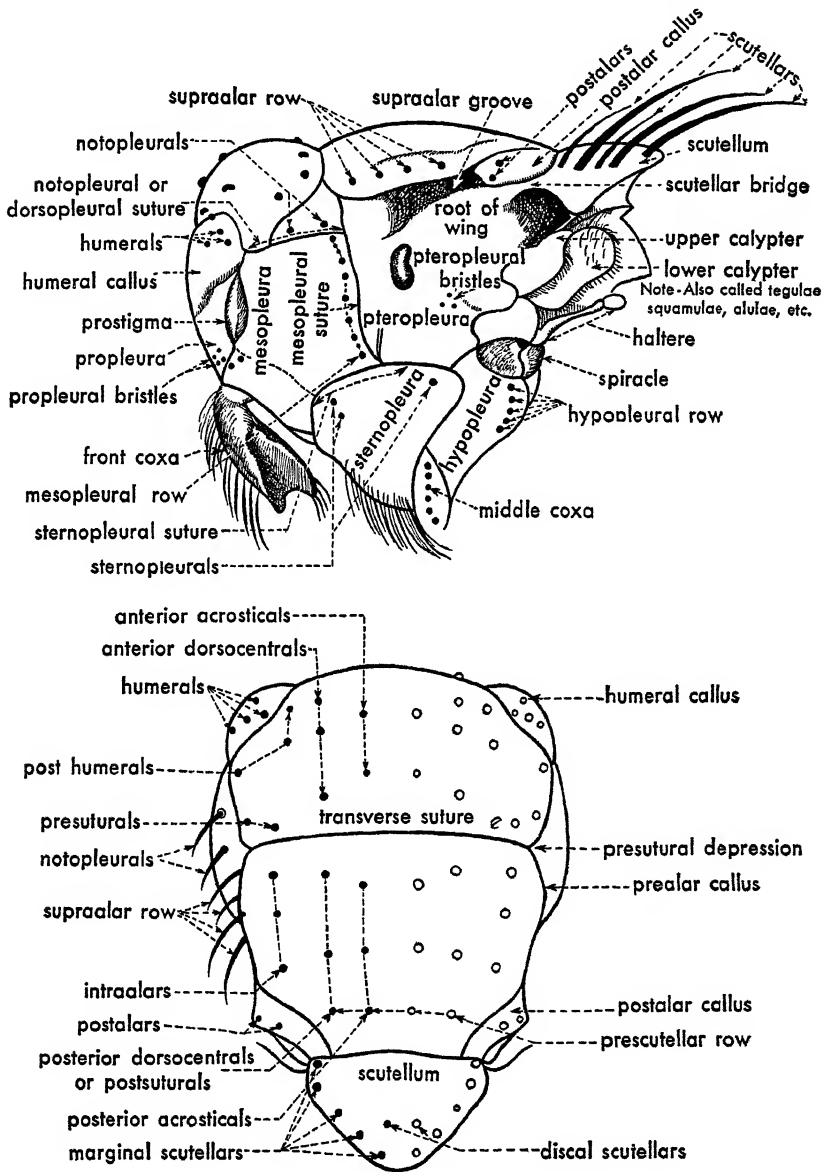


FIG. 263. Lateral and dorsal aspects of the thorax of the greenbottle fly, *Calliphora vicina* Desvoidy, with chaetotaxy and anatomical terms used in describing DIPTERA. (After Walton, 1909.)

swift runners, skaters on the surface of the water, and a few have the wings and legs modified for swimming under water. A number of remarkable forms ride on the bodies of other insects.

The food habits of the larval and adult flies are often very different even within the same species. In general they may be grouped as predacious upon other small insects and lower animals, transitory and permanent parasites, bloodsuckers, phytophagous, and commensal. These will be discussed more in detail under the families.

Reproduction is normally sexual and oviparous, but parthenogenesis and rarely pædogenesis, or larvæ born of larvæ, occur, the latter in the celebrated

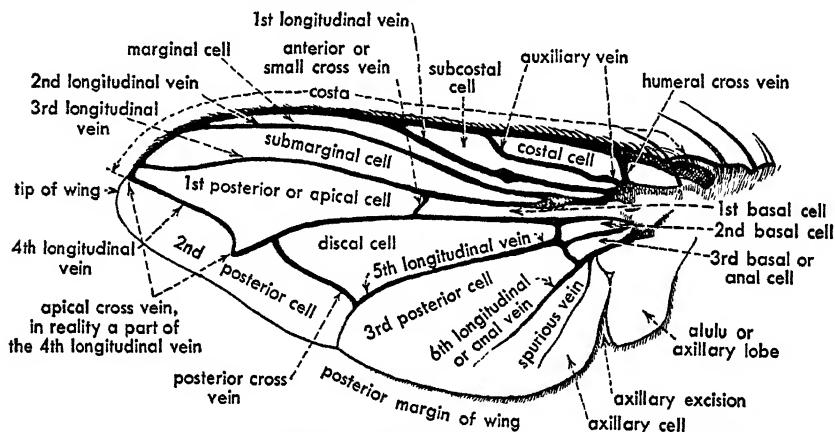


FIG. 264. Wing of *Calliphora viridescens* Desvoidy. (After Walton, 1909.)

Miastor Meinert in the family CECIDOMYIIDÆ. Young living and even mature larvæ and adults are produced by viviparous females of specialized species. Oviposition occurs in many peculiar ways. Ordinarily the eggs are deposited singly or in clusters on or near the food or in the habitat of the larvæ. In certain instances they are deposited beneath the water, in the soil, inside the tissues of plants, on living hosts, and other places. Sexual dimorphism is apparent in many species and consists in smaller, more brightly colored and ornamented males in which the appendages may also be greatly modified in size and form.

Mimicry of the Batesian type is very apparent among flies, and species in many families may resemble bees, wasps, and other insects.

In size the adults vary from the tiny no-see-um, *Leptoconops carteri* Hoffman, 1.5–2.0 mm. long, of western North America to the large Australian robber fly, *Phellus glaucus* Walker, 50 mm. long and with a wing expanse of 86 mm. The large crane fly, *Tipula broddignagia* Westwood, of China has a wing expanse of 100 mm. (Sharp, 1899).

The order is medium-sized if we are to judge from the 73,000 described species, which may represent not even half of the existing forms.

FOSSIL RECORDS

The first true fossils of DIPTERA appear in the Upper Lias (Triassic) of Europe and consist of members of the archaic family ARCHITIPULIDÆ Tillyard 1933 of England and the recent families RHYPHIDÆ Macquart 1838, of Australia, and the cosmopolitan BIBIONIDÆ. In the Tertiary the higher families, including the SYRPHIDÆ, CULICIDÆ, TACHINIDÆ, and others, appear and become abundant in the Oligocene. The most recent families are the parasitic OESTRIDÆ and HIPPOBOSCIDÆ.

IMPORTANT EXTERNAL ANATOMICAL CHARACTERS

<i>Adults</i>	<i>Larvæ or Maggots</i>
Size — minute to medium; 0.5–50.0 mm. long; wing expanse 1–100 mm.	Size — minute to large; 2–50 mm. long
Shape — relatively short, slender, or wide; somewhat flattened or cylindrical; a few nearly globular.	Shape — dipteroid, vermiform, or spindle-shaped.
Integument — thin, parchment-like, elastic, or delicate; a few tough and leathery.	Integument — thick, tough, elastic, or very delicate and easily ruptured.
Vestiture — mostly sparsely clothed with setæ, spines, and hairs; some with scales on bodies and wings.	Vestiture — usually naked; setæ, spines, and hairs may be present.
Color — varied; dull and somber, or bright; many metallic. Wings often pigmented, colored or spotted (pictured).	Color — transparent, white, yellowish, or pigmented brown, black, and other somber colors.
Head — hypognathous or nearly so; free, with small neck.	Head — very greatly reduced or rarely well developed in lower forms.
<i>Eyes</i> — large, often occupying much of the head; holoptic in some males; frequently translucent red in color; rarely divided.	<i>Eyes</i> — absent or present in certain NEMATOCERA.
<i>Ocelli</i> — three — arranged in small triangle on frons; absent in many families.	<i>Ocelli</i> — absent.
<i>Antennæ</i> — exceedingly varied; simple or complex; usually two basal plus six–16 or up to 39 segments in simple type or three or more segments in complex type; latter with apical segment enlarged and with a simple or segmented, plain or ornamented arista; whorls of hairs or other ornaments may be present.	<i>Antennæ</i> — usually inconspicuous; one- to six-segmented in free-living forms or mere papillæ in sedentary forms.

IMPORTANT EXTERNAL ANATOMICAL CHARACTERS—*Continued*

Adults	Larvæ or Maggots
<p><i>Mouth parts</i> — modified for piercing, sucking, and lapping or atrophied and functionless, especially in the males; forming a rostrum or proboscis. <i>Labrum</i> — narrow, sometimes modified for piercing.</p> <p><i>Mandibles</i> — present as piercing organs in few families, and rarely chewing. <i>Hypopharynx</i> — needle-like or spear-shaped, retractile, piercing organ. <i>Maxillæ</i> — well developed, highly specialized, or absent. <i>Labium</i> — variable, thick, and ending in two lobes or labella used in lapping, scraping, and sucking up fluids; or slender and lancet-like. <i>Proboscis</i> — composed of labrum, hypopharynx, and labium; rigid or flexible; for lapping, rasping and sucking or for piercing and sucking.</p>	<p><i>Mouth parts</i> — variable, usually reduced.</p> <p><i>Labrum</i> — may be present. <i>Mandibles</i> — vertical or horizontal. <i>Labium</i> — well developed in lower forms. <i>Cephalopharyngeal skeleton</i> or framework consists of (1) mandibular sclerites or mouth hooks which are dentate in phytophagous species, sharp and simple in carnivorous forms, and reduced in parasites; mouth hooks in vertical plane, (2) intermediate sclerite, (3) pharyngeal sclerite.</p>
<p><i>Ptilinum</i> — a retractile, bladder-like organ exerted from the frontal lunule or infolding of the epidermis on the frons above the bases of the antennæ. Employed to break the puparium and to emerge from mud bee and wasp cells and from the ground.</p>	
<p>Thorax — the segments closely fused. <i>Mesothorax</i> — largest and supporting the functional pair of wings. <i>Metathorax</i> — normally with a pair of halteres. <i>Scutellum</i> — usually conspicuous.</p>	<p>Thorax — undifferentiated in most forms.</p>
<p><i>Wings</i> — one pair, well developed, reduced, or absent; with more longitudinal than cross veins. <i>Alula</i> — a free lobe near the base of the inner or posterior margin of the wing. <i>Squamæ</i> — one or two lobes or scales, the upper and lower, connecting the wings with the thorax. In the CALYPTRATÆ they are large and are often referred to as <i>calypteres</i> or <i>calyptrons</i>. <i>Halteres</i> — vestigial hind wings; slender, knobbed organs or balancers; absent in a very few species; aid in flight.</p>	

IMPORTANT EXTERNAL ANATOMICAL CHARACTERS—*Continued*

<i>Adults</i>	<i>Larvæ or Maggots</i>
<p><i>Legs</i> — greatly variable in length and sturdiness; usually hairy; <i>coxæ</i> — short or very long; <i>tibiæ</i> with one to three spurs; <i>tarsi</i> — five-segmented; <i>claws</i> — one pair with <i>empodium</i> and may have two <i>pulvilli</i>; often only two pairs used in resting; fore pair raised in midges; middle pair raised in certain fungous gnats; hind pair raised in some mosquitoes.</p>	<p><i>Legs</i> — absent; pseudopods, one to eight pairs including the anal pair may be present in free-living forms.</p>
<p><i>Spiracles</i> — two pairs.</p>	<p><i>Spiracles</i> — various types: (1) <i>Peripneustic</i> — with functional spiracles on most abdominal segments; thoracic spiracles closed, (2) <i>Polypneustic</i> — at least three pairs of functional spiracles, (3) <i>Propneustic</i> — only the thoracic spiracles functional, (4) <i>Amphipneustic</i> — with the first or prothoracic and one or two pairs of posterior abdominal spiracles open, (5) <i>Metapneustic</i> — only the terminal pair of abdominal spiracles functional, (6) <i>Apneustic</i> — without spiracles; the oxygen is taken through the skin or by tracheal gills.</p>
<p>Abdomen — distinctly segmented, variable number of segments visible — four, five, or 11; I and II reduced and often invisible; VII to X may form ovipositor. <i>Spiracles</i> — eight pairs.</p>	<p>Abdomen — elongated, distinctly or indistinctly segmented, greatly elongated and usually with spiracles or gills present.</p>
<p>Genitalia. <i>Female</i> — internal. <i>Ovipositor</i> — may be present, formed by the four apical abdominal segments or by valves. <i>Male</i> — in crane flies the hypopygium is formed by the upcurved segments IX and X with ædeagus dorsad. Claspers and side pieces on segment IX; ædeagus between segments IX and X.</p>	<p>Pupæ free or enclosed in the final or last two larval skins which form a puparium.</p>

INTERNAL ANATOMICAL CHARACTERS OF ADULTS

Digestive System.

Buccal cavity and *pharyngeal pump* transport liquid food into the *oesophagus*.
Oesophagus — extends through the head and then divides into two branches.

The first and more direct branch leads to the *proventriculus* and the other more slender one connects with the crop or food reservoir.

Proventriculus — small muscular tubular or sac- or disk-like organ without grinding surfaces and usually with a valve.

Crop or food reservoir — normally present, rarely absent in some families; appears to be an enlargement of the branch of the *oesophagus*; simple,

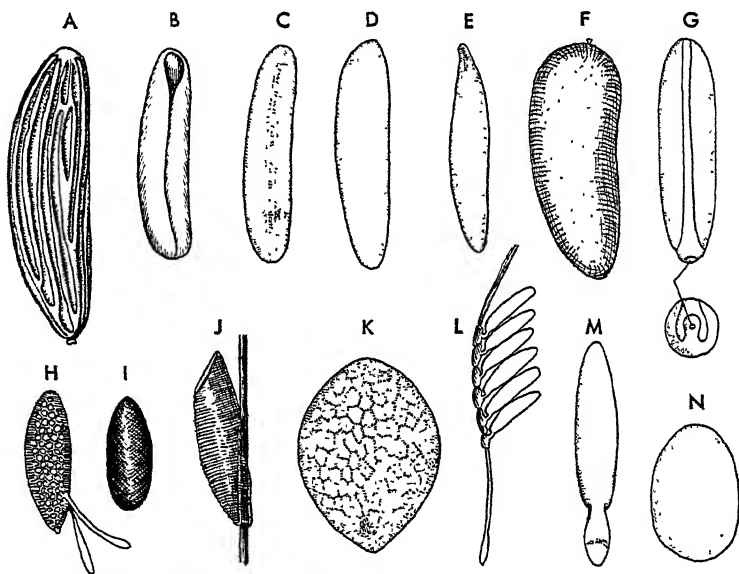


FIG. 265. Eggs of DIPTERA. A, *Hippelates pusio* Loew (after Herms and Burgess); B, *Stomoxys calcitrans* (Linn.) (after Bishopp, U.S.D.A.); C, *Cochliomyia macellaria* (Fab.) (after Bishopp, U.S.D.A.); D, *Musca domestica* Linn. (after Howard, U.S.D.A.); E, *Tabanus unctifer* O.S. (after Webb and Wells, U.S.D.A.); F, *Cryptochætum iceryæ* (Williston) (after Thorpe); G, *Cochliomyia americana* Cushing and Patton (after Lake, U.S.D.A.); H, *Drosophila melanogaster* Meiger (after Martelli); I, *Tipula infusca* Loew (after Hyslop, U.S.D.A.); J, *Gasterophilus nasalis* (Linn.) (after Bishopp and Dove, U.S.D.A.); K, *Zenillia libatrix* (Panzer) (after Dowden); L, *Hypoderma lineata* De Villiers attached to a hair and M, dorsal aspect of single egg (after U.S.D.A.); N, *Simulium simile* Malloch (after Cameron, Canada Dept. Agr.).

bilobed, or three-chambered with thin delicate walls, strengthened externally by a network of muscle tissues; empties into the *oesophagus*.

Mid-intestine — spindle- or pear-shaped, tubular, and convoluted; divided anteriorly into the *ventriculus* or *chyle stomach* and posteriorly into a narrower *proximal intestine*.

Malpighian tubes — two, four, or five pairs; normally four.

Hind intestine — tubular and but slightly convoluted; divisible distally into the *ileum* and *colon* and posteriorly into the *rectum* which is furnished with two, four, or six *papillæ*.

Circulatory System.

Not well known for the order as a whole. In higher groups the heart is composed of four large chambers, each with two posterior *ostia* and prolonged anteriorly into a narrow tube. Circulation is also through the wings of some flies.

Tracheal System.

Well developed and permitting great activity. Special air sacs are present in the head, thorax, and abdomen and are particularly large in the latter. Usually two thoracic and seven or eight abdominal spiracles are present.

Nervous System.

Variable. The head ganglia are intimately fused, and the arrangement of the number of thoracic and abdominal ganglia includes such combinations as 1-0, 1-1, 1-2, 2-0, 2-4, 2-6, 3-5, 3-7.

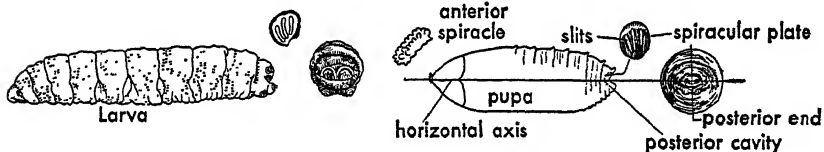


FIG. 266. The larva or maggot and pupa or puparium of the blowfly, *Sarcophaga cistudinis* Aldrich. (After Greene, 1925.)

Reproductive System.

The reproductive system is well developed, and flies are among the most prolific of insects. In view of the many different methods of bringing forth young, the systems are greatly modified and specialized.

Female. — *Ovarioles* — polytrophic, variable in number; one or two or from five to 100 on each side or a number enclosed in a membrane. *Spermatheca* — present, prominent, pigmented, globular, chitinous-lined sacs; one—three in number.

Accessory glands — paired or single, small or large, tubular; emptying into upper part of the vagina; furnish excretions to fasten eggs or to nourish intrauterine larvæ.

Male—*Testes* — ovoid, pyriform, usually pigmented. *Vasa deferentia* — short, united into a common *ejaculatory duct*. *Ejaculatory sac* and paired *accessory glands* present in many species (Imms, 1934).

LIST OF MOST IMPORTANT FAMILIES

(Family names agreed upon by nearly all workers are starred.)

A. Group ORTHORRHAPHA Brauer 1863

I. Suborder NEMATOCERA (Latreille 1825) Brauer 1880

a. Series PROTOPHTHALMA Enderlein 1936

1. Family ANISOPODIDÆ
2. " * DEUTEROPHLEBIIDÆ
3. " * BLEPHAROCERATIDÆ (BLEPHAROCERIDÆ)
4. " * BIBIONIDÆ
5. " PACHYNEURIDÆ
6. " HESPERINIDÆ
7. " * MYCETOPHILIDÆ (FUNGIVORIDÆ)
8. " SCIOPHILIDÆ
9. " BOLITOPHILIDÆ
10. " DIADOCIDIIDÆ
11. " DITOMYIDÆ
12. " MYCETOBIDÆ
13. " CEROPLATIDÆ
14. " MACROCERATIDÆ (MACROCERIDÆ)

b. Series POLYNEURA Malloch 1917

15. Family TRICHOCERATIDÆ
16. " * CYLINDROTOMIDÆ
17. " * LIMONIIDÆ (LIMNOBATIDÆ)
18. " * TIPULIDÆ

c. Series OLIGONEURA Schiner 1863

19. Family * TANYDERIDÆ
20. " PTYCHOPTERIDÆ
21. " * PSYCHODIDÆ
22. " * DIXIDÆ
23. " * CULICIDÆ
24. " * CHAOBORIDÆ
25. " * SIMULIIDÆ (MELUSINIDÆ)
26. " * CHIRONOMIDÆ (TENDIPEDIDÆ)
27. " * CERATOPOGONIDÆ (HELEIDÆ)

d. Series ZYGOPHTHALMA Enderlein 1912

28. Family * SCATOPSIDÆ
29. " CORYNOSCERIDÆ
30. " SCIARIDÆ (LYCORIIDÆ)
31. " CAMPYLAMYIDÆ
32. " HETEROPEZIDÆ
33. " * CECIDOMYIIDÆ (CECIDOMYIDÆ, ITONIDIDÆ)

II. Suborder BRACHYCERA Brauer 1880

e. Series HOMEOACTYLA Brauer 1883

34. Family XYLOPHAGIDÆ
35. " * STRATIOMYIDÆ (STRATIOMYIIDÆ)
36. " CHIROMYZIDÆ

- 37. Family *CÆNOMYIIDÆ
- 38. " SOLVIDÆ (XYLOMYIIDÆ)
- 39. " *TABANIDÆ
- 40. " *PANTOPHTHALMIDÆ
- 41. " *NEMESTRINIDÆ
- 42. " ACROCERATIDÆ (ACROCERIDÆ, CYRTIDÆ, HENOPI-
DÆ, ONCODIDÆ)

f. Series HETERODACTYLA Brauer 1883

- 43. Family *THEREVIDÆ
- 44. " *RHAGIONIDÆ (LEPTIDÆ)
- 45. " RACHICERIDÆ
- 46. " *APIOCERATIDÆ (APIOCERIDÆ)
- 47. " *SCENOPINIDÆ (OMPHRALIDÆ)
- 48. " *MYDAIDÆ
- 49. " *BOMBYLIIDÆ
- 50. " *ASILIDÆ

III. Suborder PROSECHOMORPHA Enderlein 1936

- 51. Family *THAUMALEIDÆ

IV. Suborder GEPHYRONEURA Enderlein 1936

- 52. Family SCIADOCERATIDÆ
- 53. " *EMPIDIDÆ (EMPIDÆ)
- 54. " *LONCHOPTERIDÆ (MUSIDORIDÆ)
- 55. " *DOLICHOPODIDÆ (DOLICHOPIDÆ)

B. Group CYCLORRHAPHA Brauer 1880

V. Suborder ASCHIZA Becker 1882

- 56. Family *PHORIDÆ
- 57. " *BRAULIDÆ
- 58. " SCIADOCERATIDÆ (Also included here by authors)
- 59. " THAUMATOXENIDÆ
- 60. " *PLATYPEZIDÆ (CLYTHIIDÆ)
- 61. " *SYRPHIDÆ
- 62. " *PIPUNCULIDÆ (DORYLAIDÆ)
- 58a. Family TERMITOMASTIDÆ
- 58b. " TERMITOXENIIDÆ

VI. Suborder SCHIZOPHORA Becker 1882

g. Series ARCHISCHIZA Enderlein 1936

- 63. Family *CONOPIDÆ

h. Series PROTOMUSCARIA Enderlein 1936

- 64. Family *SCATOPHAGIDÆ
- 65. " CORDYLURIDÆ
- 66. " *TACHINISCIDÆ
- 67. " *PYTHALMIIDÆ

i. Series ACALYPTRATÆ Macquart 1835

- 68. Family *DRYOMYZIDÆ
- 69. " *NEOTTIOPHILIDÆ
- 70. " *SEPSIDÆ

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71. Family * MEGAMERINIDÆ
 72. " * PIOPHILIDÆ
 73. " * PSILIDÆ
 74. " CALOBATIDÆ
 75. " MICROPEZIDÆ (TYLIDÆ)
 76. " * NERIIDÆ
 77. " * PALLOPTERIDÆ
 78. " * LONCHÆIDÆ
 79. " * RHOPALOMERIDÆ
 80. " * RHINOTORIDÆ
 81. " * TANYPEZIDÆ
 82. " * NOTHYBIDÆ
 83. " * PYRGOTIDÆ
 84. " ULIDIIDÆ
 85. " PTEROCALLIDÆ
 86. " OTITIDÆ (ORTALIDÆ)
 87. " * RICHARDIIDÆ
 88. " PLATYSTOMATIDÆ (PLATYSTOMIDÆ)
 89. " PHYTALMIIDÆ
 90. " * TRYPETIDÆ (TEPHRITIDÆ, TRUPANEIDÆ)
 91. " LAUXANIIDÆ (SAPROMYZIDÆ)
 92. " CHAMÆMYIIDÆ (OCHTHIPHILIDÆ)
 93. " TETANOCERATIDÆ (TETANOCERIDÆ, SCIOMYZIDÆ)
 94. " * CELYPHIDÆ
 95. " CŒLOPIDÆ (PHYCODROMIDÆ)
 96. " * HELOMYZIDÆ
 97. " TRICHOSCELIDÆ
 98. " * CHYROMYIDÆ
 99. " * CLUSIIDÆ
 100. " ANTHOMYZIDÆ
 101. " * OPOMYZIDÆ (GEOMYZIDÆ, TETHINIDÆ)
 102. " * EPHYDRIDÆ
 103. " * CANACEIDÆ
 104. " * DIOPSIDÆ
 105. " * BORBORIDÆ (SPHÆROCERIDÆ, CYPSELIDÆ)
 106. " LEPTOCERATIDÆ
 107. " CURTONOTIDÆ
 108. " DIASTATIDÆ
 109. " CAMILLIDÆ
 110. " * DROSOPHILIDÆ
 111. " * PERISCELIDÆ
 112. " ASTEIIDÆ
 113. " AULACOGASTRIDÆ
 114. " CRYPTOCHÆTIDÆ
 115. " * AGROMYZIDÆ
 116. " ODINIIDÆ
 117. " PHYLLOMYZIDÆ (MILICHIIDÆ)
 118. " LEPTOCERIDÆ
 119. " * CHLOROPIDÆ (OSCINIDÆ)

120. Family * THYREOPHORIDÆ
j. Series CALYPTRATÆ Macquart 1883
 (1) Superfamily MUSCOIDEA Comstock 1924
 121. Family * ANTHOMYIIDÆ
 122. " GLOSSINIDÆ
 123. " * MUSCIDÆ
 124. " STOMOXYIDÆ
 125. " * GASTEROPHILIDÆ (GASTROPHILIDÆ)
 (2) Superfamily PROTACHINOIDEA Enderlein 1936
 126. Family EGINIIDÆ
 (3) Superfamily TACHINOIDEA Enderlein 1936
 127. Family PHASIIDÆ
 128. " HYPODERMATIDÆ (HYPODERMIDÆ)
 129. " * ÆSTRIDÆ
 130. " CUTEREBRIDÆ
 131. " CALLIPHORIDÆ (METOPIIDÆ)
 132. " * SARCOPHAGIDÆ (METOPIIDÆ)
 133. " RHINOPHORIDÆ
 134. " * TACHINIDÆ (MEGAPROSOPIDÆ)
 135. " * DEXIIDÆ
k. Series PUPIPARA Nitzsch 1818
 136. Family * HIPPOBOSCIDÆ
 137. " * STREBLIDÆ
 138. " * NYCTERIBIIDÆ

KEY TO FAMILIES¹

1. Wings absent or greatly reduced 91
 Wings present, rarely reduced 2
 2. Antennæ composed of six or more freely articulated segments . 3
 Antennæ composed of not more than five freely articulated segments,
 the third segment sometimes complex, usually bearing a style or
 arista 22
 3. Mesonotum with an entire V-shaped suture 4
 Mesonotal suture transverse, not V-shaped 7
 4. Ocelli absent 5
 Ocelli present. (Winter Crane Flies.) (TRICHOCERIDÆ)
 TRICHOCERATIDÆ p. 751
 5. Only one anal vein reaches the wing margin 6
 Two anal veins reach the wing margin. (Crane Flies.) . . . TIPULIDÆ p. 748
 6. Second and third veins each with two branches (radius five-branched.)
 (Primitive Crane Flies.) TANYDERIDÆ p. 750
 Second and third veins with only three branches reaching the wing
 margin (radius four-branched). (False Crane Flies.)
 PTYCHOPTERIDÆ p. 750
 7. Wings without a network of folds or creases 8
 Wings with a network of fine folds or creases. (Net-winged Midges.)
 BLEPHAROCERATIDÆ p. 751

¹ This key is from *The Families and Genera of North American Diptera*, by C. H. Curran, who kindly gave permission for its use in this work. Only a few changes in family nomenclature have been made.

8. Ocelli present 9
Ocelli absent 14
9. Costa continuing around the wing, although weakened behind. (Gall Gnats, Gall Midges.) **CECIDOMYIIDÆ** p. 762
Costa ending at or near the wing-tip 10
10. Discal cell present 21
Discal cell absent 11
11. Tibiæ with apical spurs 12
Tibiæ without apical spurs though produced spur-like. (Minute Black Scavenger Flies.) **SCATOPSIDÆ**
12. Eyes more or less connected by a projection above the base of the antennæ. (Root Gnats, Dark-winged Fungus Gnats.) **SCIARIDÆ** p. 812
Eyes separated 13
13. Antennæ placed below the compound eyes, usually close to the oral margin. (March Flies.) **BIBIONIDÆ** p. 746
Antennæ situated at most slightly below the middle of the compound eyes. (Fungus Gnats.) **MYCETOPHILIDÆ** p. 747
14. Costa continued around the margin of the wings, though weaker behind the apex. 17
Costa ending at or near the apex of the wing 15
15. Wings very broad, the posterior veins weak and poorly developed. (Black Flies, Buffalo Gnats.) **SIMULIIDÆ** p. 758
Wings narrow and long, the posterior veins stronger 16
16. Wings lying flat over the back when at rest; metanotum short and without a longitudinal groove; femora sometimes swollen. (Biting Gnats, Punkies, No-see-ums.) **CERATOPOGONIDÆ** p. 761
Wings lying roof-like over the back when at rest; metanotum long and with a median longitudinal groove; legs long and slender. (Midges, Gnats.) **CHIRONOMIDÆ** p. 759
17. Wings short and broad, folded roof-like over the body when at rest, usually pointed. (Moth Flies, Owl Midges, Sand Flies.) **PSYCHODIDÆ** p. 751
Wings long, or if broad, the apex very broadly rounded, always lying flat over the back when at rest 18
18. Venation very much reduced, several of the veins lacking. (Fungus Gnats.) **CECIDOMYIIDÆ** p. 762
Venation not reduced, the veins strong 19
19. Basal cells long, extending to or beyond the middle of the wing 20
Basal cells, especially the second, short, not extending nearly to the middle of the wings. (Stream Midges.) **THAUMALEDIDÆ**
20. Apical veins strongly arched. (Dixa Flies.) **DIXIDÆ** p. 812
Veins straight or nearly so. (Mosquitoes.) **CULICIDÆ** p. 752
21. Fourth posterior cell widely open. (Wood Gnats.) **ANISOPODIDÆ**
Fourth posterior cell closed **RACHICERIDÆ**
22. Empodium developed pulvilliform, the three pads nearly equal 23
Empodium hair-like or absent 29
23. Third antennal segment compound, composed of annuli 24
Third antennal segment simple, usually bearing an elongated style or arista 27

24. Squamæ large and conspicuous. (Horseflies, Deer Flies, Gadflies.)	TABANIDÆ	p. 766
Squamæ small or vestigial	25	
25. At least the middle tibiæ with spurs	CENOMYIDÆ	
Tibial spurs absent	26	
26. Posterior branch of the third vein ending before the wing-tip. (Soldier Flies.)	STRATIOMYIDÆ	p. 765
Posterior branch of the third vein ending well behind the wing-tip. (Wood-boring Flies.)	PANTOPHTHALMIDÆ	
27. Squamæ very large; head very small, placed low down, composed almost entirely of the eyes, the face and front very narrow or obliterated. (Small-headed Flies.)	(CYRTIDÆ) ACROCERATIDÆ	p. 768
Squamæ small; head larger, the face or front broad	28	
28. Middle tibiæ with spurs; venation not complex. (Snipe Flies.)	RHAGIONIDÆ	p. 769
Tibiæ without spurs; venation intricate, many veins ending before the wing-tip. (Hairy Flies.)	NEMESTRINIDÆ	
29. Wings rounded apically, with strong veins anteriorly and very weak, oblique ones; coxæ not widely separated by the sternum. (Phorid Flies.)	PHORIDÆ	p. 778
Wings with normal venation or pointed at the apex, or the coxæ broadly separated by the sternum	30	
30. Wings pointed at the apex, without cross veins. (Pointed-winged Flies.)	LONCHOPTERIDÆ	
Wings rounded at apex, almost always with cross veins	31	
31. Two or more submarginal cells, the third vein furcate	32	
Only one submarginal cell, the third vein simple	38	
32. Front hollowed between the eyes, strongly concave from anterior view	33	
Front scarcely or not at all concave from anterior view	34	
33. At most one ocellus; at most two veins reach the wing margin behind the apex. (Mydas Flies.)	MYDAIDÆ	p. 771
Three ocelli; at least four veins reach the wing margin, or extend towards it, behind the apex. (Robber Flies.)	ASILIDÆ	p. 774
34. Costa continuing around the wing; fourth vein ending beyond the wing-tip	35	
Costa not continued beyond the apex of the wing; fourth vein ending before the wing-tip. (Window Flies.)	SCENOPINIDÆ	
35. Five posterior cells	36	
At most four posterior cells	37	
36. Fourth vein ending before the apex of the wing. (Flower-loving Flies.)	APIOCERATIDÆ	
Fourth vein ending behind the apex of the wing. (Stillete Flies.)	THEREVIDÆ	p. 772
37. Anal cell open or closed near the wing margin, the anal vein reaching the margin. (Bee Flies.)	BOMBYLIIDÆ	p. 772
Anal cell closed far from the wing margin, the anal vein never extending to the margin, sometimes absent. (Dance Flies.)	EMPIDIDÆ	p. 775

38. Anal cell elongate, tapering and acute apically, closed near the border of the wing; basal cells usually elongate 39
 Anal cell short, transverse, oblique, or convex apically, if somewhat pointed the apex partly transverse, partly drawn out into a triangular point posteriorly 40
39. Anal cell closed very close to the wing margin; a spurious vein running obliquely between the third and fourth longitudinal veins. (Syrphid Flies, Flower Flies.) **SYRPHIDÆ** p. 781
 Anal cell usually shorter; no spurious vein 40
40. Head extremely large, hemispherical, the front and face very narrow, arista dorsal. (Big-headed Flies.) **PIPUNCULIDÆ** p. 785
 Head not usually large, face or front usually wide 41
41. Frontal lunule entirely absent, the parafacials not differentiated by a suture 42
 Frontal lunule present, parafacials differentiated by a suture which extends above the antennæ and is indistinct only in some
CONOPIDÆ 44
42. Anterior cross vein situated at or before the basal fourth of the wing; second basal and discal cells always united. (Long-legged Flies, Long-headed Flies.) **DOLICHOPODIDÆ** p. 776
 Anterior cross vein situated far beyond the basal fourth of the wing or the second basal cell complete 43
43. Anal cell pointed posteriorly; proboscis never rigid and adapted for piercing. (Flat-footed Flies.) **PLATYPEZIDÆ** p. 780
 Anal cell not pointed posteriorly; proboscis usually rigid; never a single row of acrostical hairs. (Dance Flies.) **EMPIDIDÆ** p. 775
44. Coxæ close together at the base, the legs attached ventrally 45
 Coxæ widely separated at the base, the legs attached towards the sides of the thorax; usually leathery or coriaceous flies; ectoparasites
(PUPIPARA) 91
45. Second antennal segment with a longitudinal seam along the upper outer edge extending almost the whole length; posterior calli definitely formed by a depression extending from behind the base of the wings to above the base of the scutellum
(CALYPTRATÆ; MUSCOIDEA) 85
 Second antennal segment rarely with a well-developed dorsal seam, the posterior calli not differentiated (except in *Gasterophilus*); squamæ small **(ACALYPTRATÆ)** 46
46. Mouth parts vestigial, sunken in a very small oral pit. (Gadflies, Horse Botflies.) **GASTEROPHILIDÆ** p. 802
 Mouth parts well developed, the oral opening large 47
47. Posterior spiracle with several hairs on the border in addition to the pubescence (visible only with high magnification) 50
 Posterior spiracle with pubescence only 48
48. Subcosta complete, free from the first vein and ending in the costa (cf. **TRYPETIDÆ**) 64
 Subcosta incomplete, or not ending in the costa, or the apex curved forwards beyond the bend 49
49. Subcosta curved forwards at nearly a right angle and weakened beyond

- the bend, the costa fractured at the apex of the subcosta; wings almost always pictured. (Fruit Flies.) **(TRUPANEIDÆ) TRYPETIDÆ** p. 778
 Subcosta not angularly curved and weakened 51
50. Head broad, flattened above; scutellum and thorax flattened, the former elongate; large flies **RHOPALOMERIDÆ**
 Head rather spherical; scutellum usually convex, not elongate; small, cylindrical flies. (Spiny-legged Flies.) **SEPSIDÆ**
51. First segment of the posterior tarsi shortened and incrassate. (Manure Flies.) **BORBORIDÆ**
 First segment of the posterior tarsi normal, usually longer than the second 52
52. Anal cell absent. 53
 Anal cell present 55
53. Postocellar bristles divergent. (Shore Flies, Ephydrid Flies.) **EPHYDRIDÆ**
 Postocellars convergent or absent 54
54. Ocellar triangle large; fifth vein with a distinct curvature near the middle of the discal cell. (Frit Flies.) **CHLOROPIDÆ** p. 794
 Ocellar triangle small; fifth vein straight or without a sharp curvature. (Vinegar Flies.) **DROSOPHILIDÆ** p. 793
55. Costa broken at the humeral cross vein 56
 Costa not broken at the humeral cross vein 58
56. Postocellars divergent, if absent the arista absent. (Leaf-mining Flies.) **AGROMYZIDÆ** p. 794
 Postocellars convergent, parallel or absent, arista present 57
57. A pair of convergent frontal bristles anteriorly; interfrontals often present **PHYLLOMYZIDÆ**
 Anterior frontals not convergent. (Vinegar Flies.) **DROSOPHILIDÆ** p. 793
58. Postocellar bristles convergent **OPOMYZIDÆ** p. 794
 Postocellar bristles divergent or absent 59
59. Ocellar triangle large and shining, reaching the anterior edge of the front. (Seashore Flies.) **CANACEIDÆ**
 Ocellar triangle short 60
60. Second vein joining the costa just beyond the apex of the first **ASTEIIDÆ**
 Second vein joining the costa far beyond the apex of the first 61
61. Costa fractured or weakened at the apex of the auxiliary vein 62
 Costa not at all weakened **PERISCELIDÆ**
62. Oral vibrissæ present. (Leaf-mining Flies.) **AGROMYZIDÆ** p. 794
 Oral vibrissæ absent 63
63. Sternopleural bristle present **OPOMYZIDÆ** p. 794
 Sternopleural bristle absent. (Rust Flies.) **PSILIDÆ** p. 788
64. Oral vibrissæ present 65
 Oral vibrissæ absent 71
65. Mesonotum and scutellum convex, if rather flattened the abdomen and legs not bristly 66
 Mesonotum and scutellum flattened; legs and abdomen conspicuously bristly **CÆLOPIDÆ**
66. Postvertical bristles divergent 68
 Postvertical bristles convergent 67

67. Orbital plates bearing the frontal bristles short and oblique. (Sun Flies.) **HELOMYZIDÆ**
 Orbital plates long, extending to the anterior margin of the front or almost so **CHYROMYIDÆ**
68. Second basal and discal cells separated 69
 Second basal and discal cells confluent. (Vinegar Flies.) **DROSOPHILIDÆ** p. 793
69. Anterior half of the front with strong bristles, two to four pairs present on the front; third antennal segment short and rather orbicular, the arista subapical **CLUSIIDÆ**
 At most two pairs of rather weak frontal bristles situated on the posterior half; arista subbasal 70
70. Eyes round; occiput convex and prominent. (Cheese Skipper Flies.)
 **PIOPHILIDÆ** p. 788
 Eyes vertical, elongate; occiput concave; antennæ long **LONCHÆIDÆ** p. 794
71. Legs long and slender, stilt-like; apical cell narrowed 72
 Legs shorter and more robust, if rather long the apical cell not strongly narrowed 75
72. Propleura haired 73
 Propleura bare in the middle 74
73. Pteropleura haired on whole surface **TANYPEZIDÆ**
 Pteropleura bare on anterior half; second basal cell confluent with the discal **MICROPEZIDÆ**
74. Arista apical **NERIIDÆ**
 Arista dorsal **CALOBATIDÆ**
75. Apical cell closed or almost so in the wing margin; abdomen cylindrical, the genitalia usually large. (Thick-headed Flies.) **CONOPIDÆ** p. 786
 Apical cell not strongly narrowed or the abdomen short and broad 76
76. Some or all of the tibæ with preapical dorsal bristle 77
 Tibæ without preapical bristle 80
77. Postocellar bristles parallel, divergent, or absent 78
 Postocellar bristles convergent **LAUXANIIDÆ**
78. Clypeus never prominent; femora with bristles 79
 Clypeus very prominent; femora without bristles **DRYOMYZIDÆ**
79. Ovipositor flat and wide; front long and moderately narrow; head short, hemispherical, the antennæ never porrect; shining blackish flies.
 **LONCHÆIDÆ** p. 794
 Ovipositor not prominent; front wide; head more or less orbicular or the front produced; antennæ usually porrect; very rarely shining black **TETANOCERATIDÆ**
80. Antennæ situated on the eye-stalks or at their base. (Stalk-eyed Flies.)
 **DIOPSIDÆ**
 Antennæ situated on the front, though widely separated, regardless of the presence of eye-stalks 81
81. Ocelli absent **PYRGOTIDÆ**
 Ocelli present 82
82. Postocellar bristles convergent or absent 83
 Postocellar bristles divergent or parallel 84
83. Posterior femora swollen and spinose beneath; abdomen clavate; small, slender flies **MEGAMERINIDÆ**

- Posterior femora not swollen and spinose; abdomen short and rather broad, never clavate **CHAMÆMYIDÆ** p. 791
84. Presutural dorsocentrals absent or the subcostal and first veins end far apart. (Picture-winged Flies.) **OTITIDÆ** p. 789
- Presutural dorsocentrals present or the thorax bearing very long fine pile **PALLOPTERIDÆ** p. 794
85. Metascutellum developed, appearing as a strong convexity below the scutellum; hypopleura with strong bristles. (Tachina Flies.) **TACHINIDÆ** p. 809
- Metascutellum weak or absent, or if developed there is hair only on the hypopleura 86
86. Oral opening and mouth parts very small; hypopleura with abundant long hair 87
- Oral opening normal; hypopleura with a row of bristles or only short, sparse hair 88
87. Scutellum extending far beyond the base of the metanotum; metascutellum never developed. (Robust Botflies.) **CUTEREBRIDÆ** p. 805
- Scutellum very short; metascutellum usually strongly developed; palpi usually large. (Botflies.) **CESTRIDÆ** p. 804
88. Hypopleura with a row of bristles 89
- Hypopleura with fine, short hair or bare 90
89. Apical cell strongly narrowed apically (**METOPIIDÆ**) **CALLIPHORIDÆ** and **SARCOPHAGIDÆ** pp. 806, 808
- Apical cell not at all narrowed apically. (Houseflies, Stable Flies, etc.) **MUSCIDÆ** p. 798
90. Oral vibrissæ absent; mesonotum without bristles except above the wings. (Rust Flies.) **PSILIDÆ** p. 788
- Oral vibrissæ present; mesonotum with bristles **MUSCIDÆ** p. 798
91. Coxæ widely separated by the sternum; usually parasitic on warm-blooded animals 92
- Coxæ approximate basally; not parasitic on warm-blooded animals (except **STREBLIDÆ**) 95
92. Mesonotum short, resembling the abdominal segments; antennæ inserted in lateral grooves. (Bee Louse.) **BRAULIDÆ** p. 779
- Mesonotum and abdomen differentiated 93
93. Head small and narrow, folding back into a groove on the mesonotum; prosternum produced. (Bat Tick Flies.) **NYCTERIBIDÆ** p. 814
- Head not folding back in a special groove; prosternum not produced 94
94. Palpi broader than long; wings uniformly veined. (Bat Flies.) **STREBLIDÆ** p. 814
- Palpi elongate, forming a sheath for the proboscis; wing veins crowded anteriorly, weak or absent posteriorly. (Louse Flies, Flat Flies.) **HIPPOBOSCIDÆ** p. 814
95. Antennæ and mouth parts present 96
- Antennæ and mouth parts absent. (Bat Flies.) **STREBLIDÆ** p. 814
96. Antennæ consisting of six or more freely articulated segments 97
- Antennæ consisting of at most three freely articulated segments 103
97. Mesonotum without a complete, V-shaped suture 98
- Mesonotum with a complete, V-shaped suture. (Crane Flies.) **TIPULIDÆ** p. 748

98. Eyes meeting over the antennæ 99
 Eyes widely separated above the antennæ 101
99. Abdomen enormously swollen, the apical four segments slender; ter-
 mite guests. (Fungus Gnats.) **CECIDOMYIIDÆ** p. 762
 Abdomen normal 100
100. Scutellum and halteres present. (Minute Black Scavenger Flies.)
SCATOPSIDÆ
 Scutellum and halteres absent. (Root Maggots, Dark-winged Fungus
 Gnats.) **SCIARIDÆ** p. 812
101. Termite guests; ocelli absent; wings with several veins. (Moth Flies,
 Owl Midges, Sand Flies.) **PSYCHODIDÆ** p. 751
 Not termite guests 102
102. Halteres present. (Midges, Gnats.) **CHIRONOMIDÆ** p. 759
 Halteres absent. (Fungus Gnats.) **MYCETOPHILIDÆ** p. 747
103. Antennæ apparently consisting of one more or less globular segments;
 posterior femora robust and laterally compressed. (Phorid Flies.)
PHORIDÆ p. 778
 Antennæ with two or three quite evident segments; posterior femora
 not laterally compressed 104
104. Frontal lunule present 105
 Frontal lunule absent. (Dance Flies.) **EMPIDIDÆ** p. 775
105. First segment of the posterior tarsi short and swollen. (Manure Flies.)
BORBORIDÆ
 First segment of the posterior tarsi longer than the second segment
 and not swollen 106
106. Arista with long, sparse rays. (Vinegar Flies.) **DROSOPHILIDÆ** p. 793
 Arista pubescent or bare; third antennal segment orbicular; wings
 mutilated by the fly. (Sun Flies.) **HELOMYZIDÆ**

A. Group ORTHORRHAPHA Brauer 1863

I. Suborder NEMATOCERA (Latreille 1825) Brauer 1880

a. Series *PROTOPHTHALMA* Enderlein 1936

Family BIBIONIDÆ Kirby 1837 (Bib'i-on-i-dæ, from the Latin *bibio*, a small gnat said to be generated in wine). German, Haarmücken. March Flies.

Small to medium-sized, robust, mostly black, dark-gray, or reddish-brown hairy flies. Head large, free. Eyes large, divided, holoptic in males, hairy. Antennæ short, eight- to 16-segmented, moniliform; palpi four-segmented. Wings large; stigma may be prominent. Legs often with thickened femora. According to Imms, the larvæ of these flies are structurally the most primitive in the order. They have large heads, well-developed mouth parts; are peripneustic and wholly apodous. They live in and feed on decaying vegetable matter, dung, and the roots of grasses, cereals, and vegetables. The adults often appear in great numbers early in the spring and are called harlequin flies in England and March flies in North America.

The family is a relatively small one with about 500 described species. **St. Mark's fly**, *Bibio marci* Linn., 11 mm. long, is the best known European species. The larvæ of *B. hortulans* Linn. injure the roots and stems of many kinds of plants in Europe, Asia Minor, and northern Africa. *B. albipennis* Say is the commonest North American species and *B. imitator* Walker the most

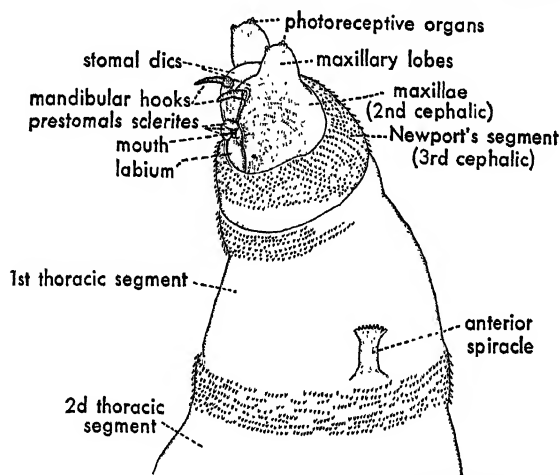


FIG. 267. Anterior region of larva of the greenbottle fly, *Lucilia sericata* Meigen, showing important structures. (Redrawn from Ellsworth, 1933.)

abundant in Australia. The genera *Dilophus* Meigen, *Hesperinus* Walker, and *Plecia* Wiedemann are common

Family MYCETOPHILIDÆ Macquart 1838 (My-ce'to-phil'i-dæ, from the Greek *μύκης*, mushroom, fungus, + *φιλεῖν*, to love; referring to the fungus-feeding habits of these flies). German, Pilzmücken. Fungus Gnats, Mushroom Flies, Mycetophilids.

Minute to small, slender, delicate, mosquito-like, active gnats; black, yellow, brown, or red in color. Body cylindrical or compressed laterally or dorsoventrally. Head small; sometimes prolonged into a proboscis. Antennæ long, filiform, 12- to 17-segmented, mostly 16-segmented; two basal segments large. Ocelli present or absent, two or three. Thorax arched. Wings large or rudimentary; several veins short or rudimentary; second basal cell open; microtrichia present. Legs slender, long; coxæ elongated; tibiæ with spurs and bristles; claws toothed and pectinate. Abdomen six- to seven-segmented. Male genitalia exerted. Ovipositor pointed. Larvæ slender, vermiform; 12-segmented; apodous; whitish or transparent, shining white, brown, or black; head chitinated; antennæ short or vestigial; peripneustic, rarely propneustic; ambulatory spines present; gregarious. The larvæ inhabit damp places and feed upon decaying vegetation and fungi. Some species are serious pests of mushrooms; others live under litter or in the soil.

The family is composed of some 2,000 species which are widely distributed throughout the world. Though few in number of species, these flies often occur in countless numbers of individuals. So abundant are they that it is difficult to find a mature toadstool or mushroom growing outdoors that is not infested. The genus *Mycetophila* Meigen contains many mushroom-infesting species, chief of which is *M. mutica* Loew, a reddish-yellow or fuscous species 2.7 mm. long and common throughout North America. Members of the European genus *Dahlica* Enderlein are wholly apterous. *D. larviformis* End. is a small, naked species of which only the female is known.

The remarkable New Zealand species, *Arachnocampa luminosa* Skuse, is luminous in the larval and adult female stages. It inhabits moist rocks in dark

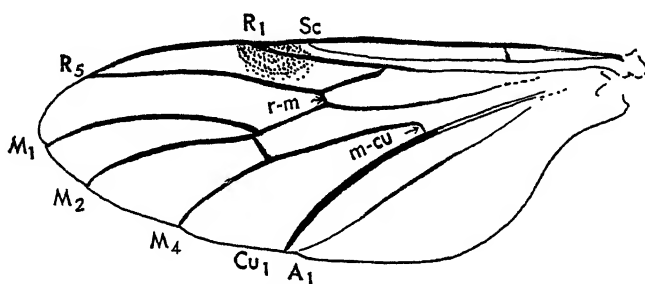


FIG. 268. Wing of the March fly, *Bibio albipennis* Say.

places and is famous in the Glowworm Cave at Waitomo, New Zealand, where the visitor, passing into the dark cavern by boat, is amazed at the thousands of lights produced by the tiny, elongated, active larvæ which are there called glowworms. This phenomenon is considered to be one of the outstanding wonders of the world (Tillyard, 1926). The fly also occurs in deep dark ravines and tunnels and spins a web upon which the larvæ rest and which serves as a reflector.

The European *Macrocera fasciata* Meigen, which lives in similar situations in the Jura Mountains of France, spins a web for capturing prey (Wheeler, 1930).

b. Series *POLYNEURA* Malloch 1917

Family TIPULIDÆ Leach 1819 (Ti-pu'li-dæ, from the Latin *tipula*, an insect that runs swiftly over the water; the water spider). German, Schnaken. Crane Flies, Daddy Long Legs.¹

Small to large, slender-bodied long-legged flies which are usually black, brown, orange, or gray and often have spotted or clouded wings. The head is prominent and may be prolonged and proboscis-like in many species. Ocelli absent. Antennæ simple in females and serrate or pectinate and sometimes very long in the males; six- to 39-segmented. Mouth parts often conspicuous, palpi

¹ This common name is also used for the so-called harvest men of the order PHALANGIDA, class ARACHNIDA.

four- to five-segmented. Mesonotum with a distinct or obscure "V" suture. Wings present, reduced, or absent; strong; costal vein encircling the wing; discal cell present, open or closed. Halteres prominent. Legs extremely long and deciduous, with or without tibial spurs. Tip of abdomen enlarged to form a hypopygium bearing coxites, styles, and ædeagus. Female with fleshy or sclerotized ovipositor. Larvæ commonly called leather jackets; fleshy, cylindrical, 11- to

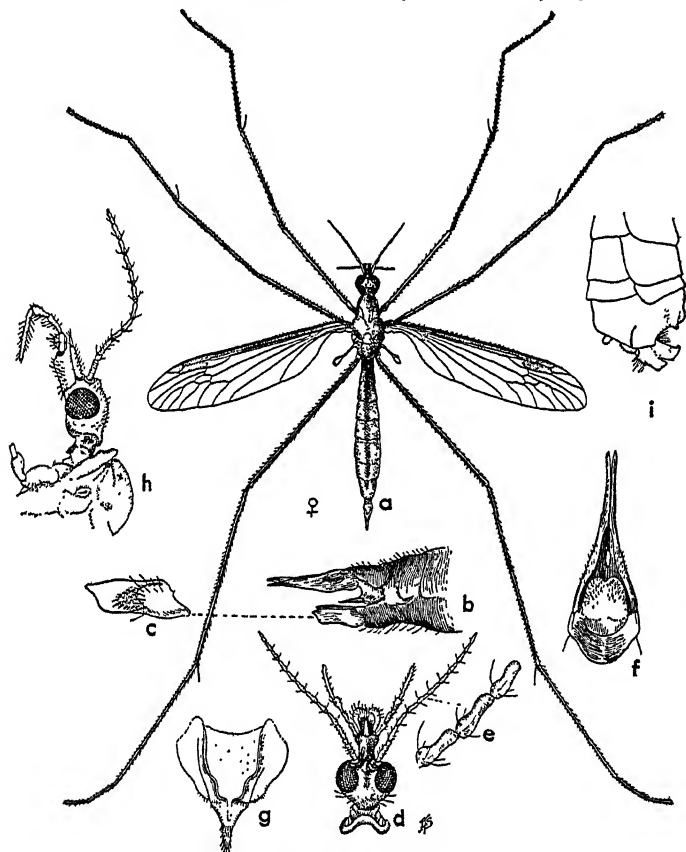


FIG. 269. The smoky crane fly, *Tipula infuscata* Loew. *a*, adult female; *b*, tip of abdomen and ovipositor; *c*, lower genital plate; *d*, dorsal aspect of head; *e*, antennal segments; *f*, ventral aspect of ovipositor with lower plates removed; *g*, lingulaform appendage of same; *h*, lateral aspect of head of male; *i*, hypopygium of male. (After Hyslop, U.S.D.A.)

12-segmented; tough, leathery integument; often rugose and pigmented or transparent; head deeply invaginated or exserted; antennæ well developed; labium large, toothed; hypopharynx large, chitinized; with or without pseudopods; spiracles on thorax and abdomen (amphipneustic) or only on anal segment (metapneustic), may be fringed in aquatic species; protrusile blood gills, proc-

esses, and filaments may also be present in aquatic species; terrestrial, semi-aquatic, or aquatic.

The females oviposit in the soil — a process that can be easily observed in late summer and autumn — or the eggs may be laid elsewhere in the larval habitat. The larvæ are phytophagous and bore into dead decaying wood; or feed upon the roots and tops of grasses or cereals; on dead and decayed vegetable matter in the soil or water; on fungi, mosses, and similar plants; and as leaf miners on living plants. Terrestrial forms prefer damp places, and the larvæ of many species appear during the rainy season.

The family is a large one, consisting of some 283 genera and over 6,000 species distributed throughout the world, being most numerous in the temperate regions. Species occurring in the polar regions and at high altitudes are often brachypterous or wingless. The family is divided into three subfamilies and five tribes (Curran, 1934). In size the adults vary from the small apterous snow gnat or snow fly, *Chionea nivicola* Doane, 4 mm. long, of North America, to such large species as the North American *Holorusia rubiginosa* Loew, 35 mm. long, wing expanse 55 mm., the Australian *Longurio dux* Hudson, 40 mm. long, wing expanse 75 mm., and the still larger Chinese *Tipula brobdignagia* Westwood, which has a wing expanse of 100 mm. The most beautiful species are the black and orange-red Australian *Clytocosmus helmsi* Skuse, and *C. tillyardi* Alexander, 35 mm. long, which mimic certain wasps of the genus *Eumenes*.

The snow gnats appear on the snow in winter and are extremely hardy, living in the northern part of North America and also at high altitudes. *Chionea valga* Harris is our commonest species. The leaf-eating crane fly, *Cylindrotoma splendens* Doane, 9–10 mm., oviposits in the tissues of false bugbane upon which the larvæ feed. It ranges into Alaska. The range crane fly, *Tipula simplex* Doane, 8–13 mm., has wingless females, and the larvæ live in holes in the soil and feed upon native grasses and planted cereals in California. Many other species of this genus have similar habits. The larvæ of the giant crane fly, *Holorusia rubiginosa* Loew, referred to above, live among the roots and stems or in the mud of water plants in slow-running streams and in ponds of the Pacific coast. They are extremely large, up to 55 mm. in length. Larvæ of the North American genus *Antocha* Osten Sacken inhabit silken cocoons attached to rocks in swift streams. Larvæ of the genus *Aphrophila* live in vegetation and debris in the mist and spray of waterfalls in Australia.

Tipula oleracea Linn., *T. paludosa* Meigen, and *Pachyrhina maculosa* Meigen all injure root crops and bulbs in Europe.

Closely related families: TANYDERIDÆ or primitive crane flies are chiefly Australian, the larvæ of which are aquatic or subaquatic and live in the sand at the margins of streams. Two genera and three species are North American. PTYCHOPTERIDÆ are false crane flies of North America whose larvæ have a very long caudal respiratory tube and live in saturated humus. The adults, called phantom crane flies, are the most delicate and ephemeral members of the group, having long downy black legs with conspicuous white bands and enlargements of the basitarsi which are referred to as gas bags by Edwards

(1931). TRICHO CERATIDÆ, or winter crane flies often appear in swarms and are most numerous during the fall, winter, and spring. The larvæ breed in wet vegetable debris. The members are Holarctic and Neotropical.

c. Series OLIGONEURA Schiner 1863

Family PSYCHODIDÆ Bigot 1854 (Psy-chod'i-dæ, from the Greek *ψυχή*, soul, a butterfly as an emblem of the soul, + *εἶδος*, form; hence, like a butterfly or moth; referring to moth-like appearance of the tiny adults). German, Schmetterlingsmücken. Moth Flies, Moth Midges, Sand Flies.

Minute hairy and scaly flies which have a hesitating running motion and fly readily; usually brown and often with wings spotted or clouded. Head small. Ocelli absent. Antennæ half as long as body, with scattered hairs and whorls of hair, 12- to 16-segmented. Mouth parts forming a short proboscis, palpi hairy, four-segmented. Wings large, hairy, and scaly, ovate or pointed; with many longitudinal veins and few basal cross veins; held roof-like over body. Abdomen six- to eight-segmented; ovipositor exserted; male genitalia large, exposed. Larvæ cylindrical, with well-developed head and eyespots; 12-segmented; some with dorsal plates and hairs; amphipneustic and metapneustic, posterior spiracle may be surrounded by four long fleshy tubercles that extend like a siphon; tracheal gills also present in certain aquatic forms which may have sucking disks on thorax; apodous.

The larvæ are largely saprophagous, being terrestrial and aquatic and feeding upon decaying vegetable matter, rotten wood, fungi, sewage, and dung. Some species live in drain pipes and emerge indoors. Aquatic forms may occur in quiet water or rushing cascades.

The adults occur in damp places and may be observed crawling over damp litter, logs, shrubbery, and tree trunks. They vary in size from the small European *Psychoda phalaenoides* (Linn.) with a wing expanse of 1.50–2.25 mm., to the largest Australian species, *Pericoma funebris* Hudson, with a wing expanse of 10 mm. The adults of most species appear to be harmless, but the so-called sand flies of the genus *Flebotomus* Rondani (*Phlebotomus*) are bloodsuckers of reptiles and mammals, and certain ones are carriers of human diseases. *F. papatasi* (Scopoli), of southern Europe and northern Africa, is the carrier of Pappataci or three-day fever in the Balkans. The South American Oroya Fever or Carrion Disease and the South and Central American Espundia are known to be transmitted by members of this genus. Leishmaniasis or kala azar of the Orient is thought to be carried by *F. argentipes* Annandale and Brunnetti in India and by *F. major* Annd. and *F. chinensis* Patton and Hindle in China.

Maruina californiensis Kellogg of California is unique among members of this family in the habits and adaptations of the larvæ to an aquatic life similar to those of the members of the family BLEPHAROCERIDÆ.

Psychoda alternata Say is widely distributed, being reported in North America and Japan.

Family CULICIDÆ Stephens 1829 (Cu-lic'i-dæ, from the Latin *culex*, a gnat). German, Stechmücken. French, Les moustiques. Mosquitoes.

Small, fragile, slender, long-legged flies with hairs and scales covering the bodies and appendages. Brown, tawny, gray, or black, often with white and paler markings, or metallic and brilliant. Head small, subglobular, with slender neck. Proboscis or labium long; rest of mouth parts piercing; palpi stiff. Eyes reniform. Ocelli absent. Antennæ long, slender, filiform; pubescent and with whorls of hairs, plumose or bushy in males; 14- to 15-segmented, first segment ring-like, second globose and cupped at extremity. Thorax compact, arched; scutellum rounded or trilobed; hairs arranged in groups on the pleuræ. Legs long and slender, fragile; coxæ short; tarsi long; claws simple or denticulate. Wings long and narrow, posterior margin fringed with hairs and scales; six longitudinal veins extend to the margins; veins beset with scales; two basal cells; plain or dappled. Halteres distinct. Abdomen slender, 10-segmented, the last two or three modified by the genitalia; male terminal three segments turned over; hypopygium consists of lobes, plates, claspers, claspettes, parameres, and side-pieces and is useful in separating the species. The larvæ or wrigglers are usually free living and active; elongated and with enlarged head, greatly enlarged fused thorax, and slender nine-segmented abdomen. Head free, with slender neck and many tufts of hairs. Antennæ short, one-segmented, with median antennal tuft of hairs. Eyes, two pairs; large compound eyes in front and smaller accessory eyes behind. Mouth parts complicated, consisting of labrum, prominent toothed mandibles, large flattened maxillæ, short palpi, labial plates, and two dense mouth brushes. Thorax with large brushes of hairs. Abdomen with lateral abdominal hair tufts on segments I to VII; segment VIII has the large cylindrical chitinized respiratory siphon (absent in *Anopheles*) with comb of many very small scales in rows near base and with two large hair tufts and two rows of flattened spines called pecten. The siphon is closed by five flaps which are normally extended or spread out to catch the surface film for support. On segment IX is located the sclerotized dorsal plate, four large tracheal or anal gills, surrounding the anus, and the large prominent dorsal brush and the smaller ventral brush. The pupæ or tumblers are active and characterized by the large cephalothorax (fused head and thorax) which has a pair of conspicuous respiratory horns or trumpets and the small slender nine-segmented and tail-like abdomen with a pair of large chitinous anal paddles or fins. Both the larvæ and pupæ move by a succession of quick paddle-like motions of the abdomen.

In size mosquitoes vary from the tiny Formosan, *Aedes formosensis* Yamada, with a wing expanse of 2.5 mm. and the tropical American, *Uranotænia lowii* Theobald, with an expanse of 3 mm., to the so-called **American gallinipper**, *Psorophora ciliata* (Fab.) which has a body length of 9 mm. and a wing expanse of 15 mm. In the last the larvæ are predacious on aquatic animals and the adults are bloodsuckers.

The biology of mosquitoes is so complicated and variable that it is impossible to treat the subject adequately here. Students are referred to the many books

on mosquitoes and medical entomology for additional information. Most species are oviparous and lay large numbers of eggs in rafts on the surface of the water or on the surface of the ground in moist beds of puddles, ponds, and streams; near water courses; or at random in marshes and snow fields. Eggs de-

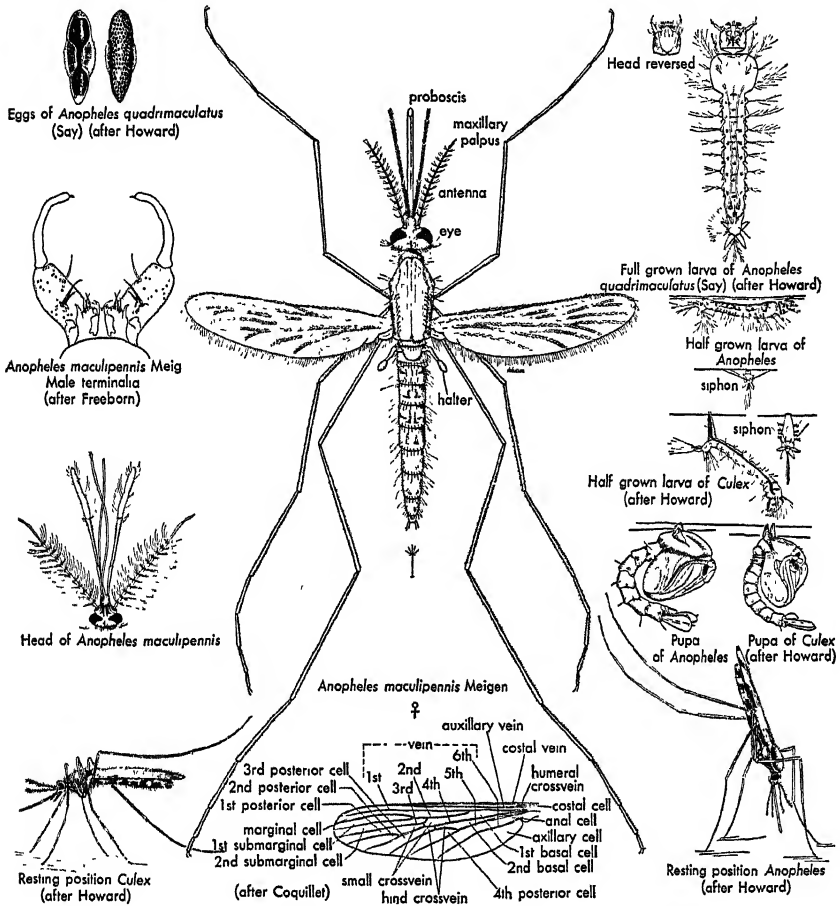


FIG. 270. Mosquitoes, CULICIDÆ. Stages in the life history and important characters. (Adult redrawn from Nuttall and Shipley, 1901.)

posited directly in the water hatch soon, but those laid on the soil usually remain during the winter or until water is supplied by nature.

The eggs are very minute, usually elongated, cylindrical or spindle-shaped, and are smooth, reticulated, or spined and furnished with floats in some species. Members of the genera *Culex*, *Theobaldia*, *Tæniorkhynchus* (*Mansonia*), and *Uranotænia* lay their eggs side by side in rafts which to some degree resemble

specks of soot floating on the surface of the water. *Anopheles* lay the eggs singly or in loose clusters on the water, and these are furnished with air floats. *Aedes* and *Psorophora* oviposit on the ground in the summer and in the high mountains hatch in the spring as soon as the snow begins to melt. Their great numbers attest to the quantities of eggs laid.

The larvæ are aquatic and live in all types of permanent and transitory fresh water as well as in brackish and salt water. Different species within the genus *Anopheles* may inhabit all these various types of water. Various species live in fresh, running, and foul water, with different amounts of algæ and plankton, variable exposures to sun or shade, in large or small bodies of water as rivers, creeks, ditches, swamps, marshes, lakes, ponds, springs, puddles, tidal pools, and in water in tree holes, tin cans, rain barrels, fish ponds, water-collecting plants, and in other temporary and artificial places. Culicine larvæ rest at the surface with the heads downwards vertically or at an angle while anophelines are suspended horizontally just beneath the surface film which they break with small float hairs for a considerable distance posteriorly and only a short distance anteriorly. They feed upon minute algæ and other plankton on the surface of or in the water. Certain members of the genera *Tæniorhynchus* and *Ficalbia* Theobald are able to puncture water plants with the siphon and thus obtain air.

The family is not large in numbers of genera and species, but it is monstrous in numbers of individuals. There are approximately 89 world genera and subgenera of which some 39 are North American. The most important and interesting of these are: *Aedes* Meigen (Subgenera: *Stegomyia* Theob., 41 spp., *Ochlerotatus* Lynch-Arribalzaga, 115 spp., *Aëdimorphus* Theob., 54 spp., and *Finlaya* Theob., 92 spp.), all widely distributed throughout the world. *Anopheles* Meigen (Subgenera: *Anopheles* Meigen, 61 spp., *Myzomyia* Blanchard, 80 spp., *Nyssorhynchus* Blanchard, 17 spp.), represented in tropical or temperate regions. *Culex* Linn. (many subgenera) cosmopolitan with 309, world spp. and 65 North American spp. *Psorophora* Robineau-Desvoidy (Subgenera: *Psorophora* R.-D., 8 spp., *Janthinosoma* Lynch-Arrib., 10 spp., *Grabhamia* Theobald, 11 spp.), tropical America. *Tæniorhynchus* Lynch-Arrib. 1891 (*Mansonia* Blanchard 1901) (Subgenera: *Tæniorhynchus* Lynch-Arrib., 5 spp., *Mansonioides* Theobald 1907, 9 spp., *Rhynchotænia* Brèthes, 8 spp., *Coquilleltidia* Dyar, 27 spp.), all cosmopolitan in the tropics and warmer temperate regions. *Theobaldia* Neveu-Lemaire (= *Culiseta* Felt), 8 spp., North American. *Wyeomyia* Theobald, 3 spp., North American.

The larvæ of most mosquitoes live in fresh water, and species of all the genera listed above may live in this medium. In certain species of *Aedes*: *A. triseriatus* (Say) of the eastern states and *A. varipalpus* (Coquillett) of the west, the larvæ live in the water collected in tree holes, while those of *Wyeomyia smithii* (Coq.) inhabit the water held in the hollow leaves of the pitcher plant, *Sarracenia purpurea* Linn., growing in the peat bogs of the United States east of the Mississippi River, and *Culex pipiens* Linn., the common rain-barrel mosquito, and *C. 5-fasciata* Say, considered domestic and house species, breed in rain barrels, cans, pools, and other receptacles.

Many species live in brackish water, and the so-called salt marsh mosquitoes have gained a notorious reputation as biters. Of these latter the famous white-banded salt marsh or New Jersey mosquito, *Aedes sollicitans* (Walker), has held undisputed first place for many years. It breeds in salt marshes along the Atlantic and Gulf coasts from Maine to Texas, and many are the stories of its size and efficiency. *A. dorsalis* (Meigen) a Holarctic species, breeds in North America along the Atlantic and Pacific coasts and the shores of Hudson Bay and also inhabits fresh water in California. *A. campestris* Dyar and Knab lives in mineral pools and brackish water and ranges throughout northern North America and also breeds in fresh water. *A. squamiger* (Coq.), the California salt marsh mosquito, breeds along the Pacific coast of California, *Anopheles multi-color* Cambouliu, according to Imms (1934), lives in saline pools containing 40 grams of chlorides per liter in Libyan oases, and *A. turkhudi* Liston of India in a 2 per cent salt solution. *A. sundanicus* Rodenwaldt is a salt-water-inhabiting species in Malaysia; *A. annulipes* (Walker) lives in sea water in Australia; and *A. sacharovi* Favr. occurs in brackish water in the Mediterranean Basin.

Opifex fuscus Hutton is peculiar in that the antennæ of the males are not plumose. It lives in sea water along the rocky coasts of New Zealand (Tillyard 1926).

The common snow mosquitoes, *Aedes communis* (DeGeer) (Holarctic) and *A. ventroviitis* Dyar (western North America), hibernate in the egg stage and the larvæ breed in the temporary snow-fed pools in early summer. These are among the most pestiferous of insects in the high mountains.

Any number of other biting and annoying species might be included if space permitted, but much more important are the disease-bearing mosquitoes which have been responsible for more misery and deaths to the human race than any other animals. The mosquitoes are not victims of the disease organisms that they transmit to humans and other mammals, but merely have become the necessary intermediate hosts by taking the parasites from an infected host, preserving and incubating certain stages within their bodies, and then transmitting back to similar hosts the living active forms that also require man and other mammals to complete their life cycles. Since the females of most species appear to require one or more meals of blood for nutriment to mature their eggs, they must feed upon a suitable host, and in doing this the transfer of the disease organism takes place. The mosquito is in some cases only a mechanical vector of certain diseases.

One of the most important mosquito-borne diseases is malaria, perhaps the most serious affliction of the human race, which is caused by microscopic protozoans that attack the red blood corpuscles. Four types of malaria are produced by four different species of the parasite:

1. **Tertian malaria** by *Plasmodium vivax* (Grassi and Feletti 1890), transmitted by no less than 60 species and subspecies of *Anopheles*.
2. **African tertian fever**, caused by *Plasmodium ovale* Stephens 1922, a rare parasite closely related to *P. vivax*.

3. **Quartan malaria**, caused by *P. malariae* (Laveran 1881) and transmitted by no less than 56 species and subspecies of *Anopheles*.

4. **Æstivo-autumnal, pernicious, subtertian, or malignant tertian malaria**, caused by *P. falciparum* (Welch 1897) and transmitted by at least 67 species and subspecies of *Anopheles*.

The most important species of *Anopheles* involved in malaria transmission in North America are: *A. crucians* Wiedemann in the eastern part including Mexico, West Indies, and the Atlantic coast north into New York; Freeborn's malarial mosquito, *A. maculipennis freeborni* Aitken, common west of the Rocky Mountains; the four-spotted malaria mosquito, *A. 4-maculatus* Say, throughout the area east of the Rocky Mountains including the Gulf coast of Mexico on the south and to Canada on the north; the wayside anopheline, *A. pseudopunctipennis* Theobald, a widely distributed species occurring from northwestern Argentina in South America northwards into the southwestern United States including California (not known to be a real vector of malaria in North America north of Mexico); and the woodland malaria mosquito, *A. punctipennis* (Say), which has the widest distribution in this country: from southern Canada into Mexico. Fifteen or more additional species are important vectors of malaria in various other parts of the world.

Some other diseases transmitted by mosquitoes are: **Avian malaria**, caused by *Plasmodium gallinaceum* Brumpt 1935 and transmitted by *Aedes ægypti* (Linn.) and *A. albopictus* (Skuse); **yellow fever and dengue** transmitted by *A. ægypti* (Linn.); **Jungle yellow fever** transmitted by *A. leucocelæmus* Dyar and Shannon in tropical South America; **filariasis**, chiefly caused by *Wuchereria bancrofti* (Cobbold 1877) and *Dirofilaria immitis* (Leidy 1856) and transmitted by the genera *Aedes*, *Anopheles*, *Culex*, and *Tæniorhynchus*; and **equine encephalomyelitis**, transmitted by several species, including *Aedes nigromaculis* (Ludlow) and *A. sollicitans* (Walker), in laboratory experiments.

Mosquitoes have been distributed by commerce to many parts of the world, and now airplanes are responsible for speedy transportation of the adults. In recent years *Anopheles gambiae* Giles was transported either by fast boats or by airplanes from West Africa to Brazil where it was discovered on the east coast in March, 1930.

Family CHAOBORIDÆ Edwards 1920 (Cha-o-bor'i-dæ, from the Greek *χαῶν*, to destroy entirely, + *βορά*, flesh; from the predacious habits of the larvæ). Phantom Gnats.

Small, hairy, slender, nonbiting aquatic gnats; 3-6 mm. long; pale yellowish, brown, or black; pilose, hairy, and scaly. Head small and may be partly hidden by thorax. Eyes large. Ocelli absent. Antennæ 14- to 15-segmented; with whorls of hairs, excepting apices. Proboscis short or long. Thorax rounded or humped; may be wider than the abdomen. Legs long and slender; hairy; tibiæ with or without spurs; tarsi five-segmented, the first segment shorter or longer than the second; claws simple. Wings rather long and slender; clothed with hairs and scales. Halteres well developed, pale. Abdomen slender; nine-seg-

mented; hypopygium prominent. Eggs elongate-oval or somewhat spindle-shaped; dark; floating singly or in small or large rafts on the surface of the water.

Larvæ or "phantoms" are elongate, subcylindrical; largest anteriorly and pointed posteriorly; composed of prominent head and 12 body segments; transparent; smooth with few small tufts of hairs on the body, large anal brush; four exerted, elongated, fleshy blood gills and numerous hairs or bristles around

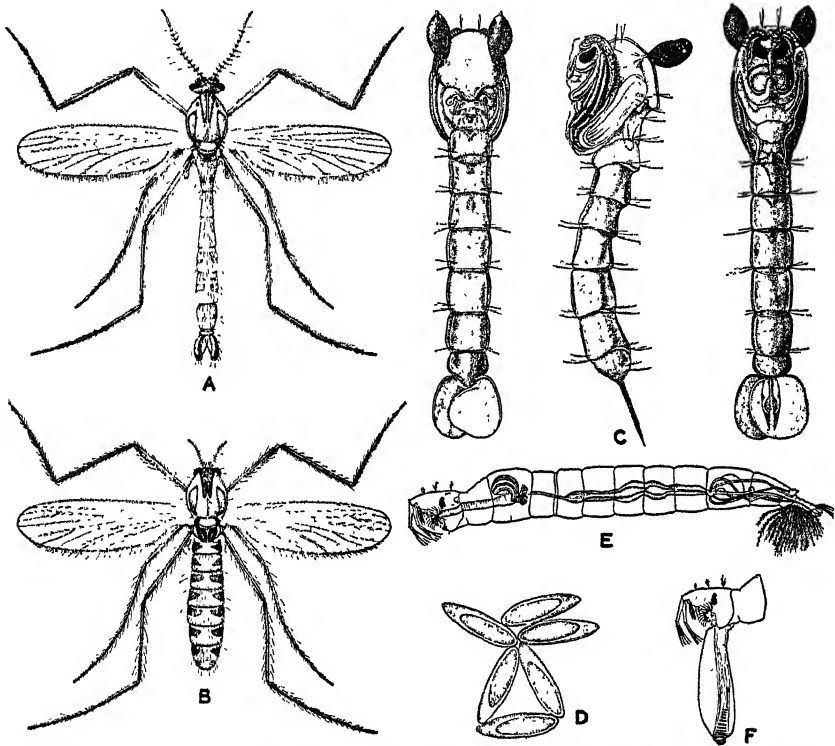


FIG. 271. The Clear Lake gnat, *Chaoborus astictopus* Dyar and Shannon. A, male; B, female; C, pupa; D, eggs; E, larva (phantom larva); F, eversible pharyngeal sac extended from the mouth. (After Herms, 1937.)

mouth; antennæ extended downwards, simple, and with three to five apical bristles that aid in securing food and in locomotion; labium with about 20 stout hairs; a pair of fans of eight to nine hairs each; mandibles consist of four separate chitinized denticles; maxillæ fleshy. The large mouth also has a spacious eversible pharyngeal sac or basket which functions as a crop for the selection of food and the rejection of extraneous materials. The larvæ have a pair of pigmented air sacs in the thorax and also in abdominal segment VII which may serve to regulate flotation and pressure. They move smoothly and rapidly through the water or they may double up and dart after the larger living prey.

The respiration is cutaneous and the larvæ live in the depths where no free oxygen remains.

The pupæ are somewhat mosquito-like with large cephalothoracic area, bladder-like respiratory tubes, and two wide flat anal paddles.

The phantom larvæ are nocturnal and feed upon plankton consisting of both animal and plant life and upon larger forms of animal life. During the day they remain on the bottom. In general they are considered beneficial because of being predacious on mosquito wrigglers and larvæ of other noxious aquatic gnats. The adults do not bite but they often appear in very great numbers about lakes in warmer areas and become a serious nuisance, particularly at resorts. Being attracted to lights, they swarm into the parks, villages, and buildings and onto the occupants.

The family is a small one consisting of less than 100 named species. It is apparently widely distributed, and many additional species probably are still awaiting discovery. The most important genus is *Chaoborus* Lichtenstein (*Corethra* Meigen). In Lake County, Calif., the Clear Lake gnat, *C. astictopus* D. & S. (= *lacustris* Freeborn), is exceedingly abundant and annoying to residents and vacationists during the spring and summer months.

The Kungu fly, *Chaoborus* sp., appears in dense cloud-like swarms that move across Lake Nyasa like low rain clouds. A few or as many as six of these huge masses of flies may be seen at one time.

The mosquito destroyer, *Eucorethra underwoodi* (Underwood) (= *americana* Johannsen) is an important enemy of mosquito larvæ in North America.

Other genera are *Corethrella* Coquillett, *Cryophila* Edwards, *Mochlonyx* Loew, and *Promochlonyx* Edwards.

Family SIMULIIDÆ Rondani 1856 (Sim'u-li'i-dæ, from the Latin *simulare*, to imitate, simulate). German, Kriebelmücken. Buffalo Gnats, Black Flies, Turkey Gnats.

Minute, robust, hump-backed, black, orange, yellowish, gray, or somber-colored gnats with short 11-segmented antennæ; large round eyes, holoptic in males, divided horizontally with upper facets larger; mouth parts for biting and sucking with horny labella and four-segmented palpi; broad naked wings with veins in the costal area prominent, others vestigial; alulæ present; short legs with tibial spurs, basal tarsal segment long and apical segment very small; seven- to eight-segmented abdomen; genitalia hidden. The larvæ are aquatic; cylindrical with disk-like "sucker" fringed with hooks on the top of the head and a similar structure at the posterior end; with three blood gills exerted from the rectal cavity. The larvæ spin cocoons, open in front and facing downstream, in which to pupate. The pupæ have two groups of prothoracic tracheal gills. The adults emerge directly from the water and often swarm in the neighborhood of swift fresh-water streams.

The females are voracious biters and bloodsuckers in some places and are one of the vacationist's greatest tormentors in many parts of the temperate and cooler regions. The eggs are deposited in great numbers on rocks and other

objects washed by spray and dashing currents or actually under the surface of the water, and the larvæ congregate in masses on the rocks in rapids, cascades, and under waterfalls where they cling to the web spun from the mouth and attached to the anchorage. The food, consisting of minute aquatic animals, algæ, and other plant life, is directed into the mouth by the brush-like hooks on the head.

These insects are not only tormentors of wild and domestic animals and man but cause painful swellings, and certain species like *Eusimulium damnosum* (Theobald) of Africa transmit to man the filaria, *Onchocera volvulus* (Leuckart), which causes a subcutaneous disease known as *onchocerciasis*. Their attacks on domestic animals and poultry have caused wholesale deaths in parts of Europe and North America. Folsom and Wardle (1934) call attention to the great scourge of these flies in Europe in 1923 when 16,474 domestic animals were killed in Roumania by the attacks of swarms of the newly emerged adults of what was probably *Simulium columbaczense* (Schiner), 2-3 mm., brown, which has long been pestiferous along the Danube.

The family is relatively small as to species, there being only about 300, but, as in many other families of flies, what is lacking in number of species is more than made up in the great hordes of individuals which may overrun certain areas within the scope of their habitats. Although many genera have been described, only four important ones are now generally recognized. Of these *Prosimulium* Roubaud and *Simulium* Latr. occur in Europe and *Eusimulium* Roubaud, *Parasimulium* Malloch, *Prosimulium* Rob., and *Simulium* Latr. inhabit North America. *Simulium* has by far the greatest number of species.

The most important North American species are: the **Adirondack black fly**, *Prosimulium hirtipes* (Fries), which occurs in eastern North America; the **yellow gnat**, *P. fulvum* (Coq.), a quick and hard biter in the western states; *Simulium vittatum* Malloch, a fierce biter, in the Pacific Northwest and ranging from New Mexico to Montana; the **turkey gnat**, *S. meridionale* Riley, at times a serious pest of turkeys, other domestic animals, and man, across the southern part of the United States; the **white-stockinged black fly**, *S. venustum* Say, with white marked tibiae, in North America east of the Rocky Mountains and north into Alaska; and *S. vittatum* Zetterstedt, the most widely distributed species occurring throughout much of the continent.

Family CHIRONOMIDÆ Rondani 1841 (Chi'ro-nom'i-dæ, from the Greek χειρονόμος, one who gestures with the hands; referring to the upraised, waving forelegs). German, Schwarmmücken. Midges.

Minute to small, delicate, long-legged flies usually not more than 5 mm. and rarely more than 10 mm. long. Head small, often partly hidden by thorax. Antennæ slender, hairy, basal segment globose, five- to 14-segmented, plumose in males. Eyes oval or reniform, smooth or pubescent. Ocelli absent or atrophied. Mouth parts forming a short proboscis, not piercing, palpi three- to four-segmented. Thorax large, with metanotal longitudinal groove. Legs slender, long, fore pair often raised when resting; tibiae with spurs; tarsi very

long in some (fore tarsi much used in classification); empodium and pulvilli absent or present. Wings absent, reduced or normal, narrow, naked or hairy with prominent longitudinal veins in costal area and remainder indistinct, with but one cross vein (r-m). Abdomen long, narrow; hypopygium exposed; ovipositor short. Eggs imbedded in mucilaginous ribbons or in debris and decayed organic matter. Larvæ slender, cylindrical, with 12 segmented legs; prolegs absent or present, one pair on thorax or one pair on thorax and one anal pair; blood gills may be present as two elongated pairs on segment XI; or two pairs papilla-like around anus; or apneustic. Surface forms are greenish, others are whitish, and certain red ones are called **blood worms** because of the presence of

hæmoglobin. The larvæ are terrestrial or aquatic.

Land forms live in and on decayed vegetation, dung, fungi, mosses, under bark, and in the soil. Aquatic species inhabit quiet or flowing water and may often become very abundant in ponds, lakes, tanks, and reservoirs. They are free living; some surface feeders; others spin cases incorporating leaves, pebbles, or debris which are attached to rocks or other objects; still others make simple cases buried in the mud with the opening at the surface of the substratum. A number of species inhabit brackish and salt lakes and the open sea.

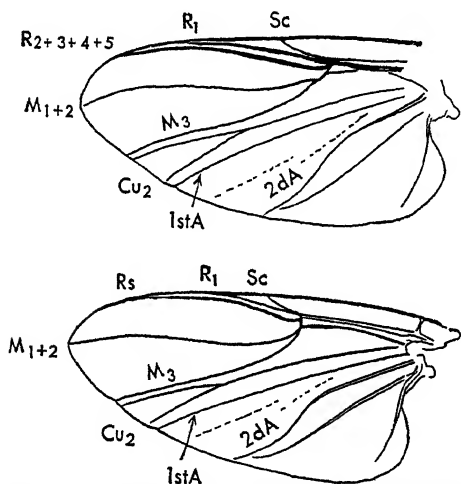


FIG. 272. Wings of the buffalo gnat, *Prosimulium fulvum* (Coquillett).

The pupæ are active or inactive; and the inactive ones may remain in the larval cases. They usually breathe by means of a pair of simple or branched tracheal tubes. The adults often appear during the day or in the evenings in great swarms, and their dancing movements may be accompanied by high-pitched notes that seem to modulate. In certain lake areas these midges may appear in clouds over the surface of the water. Tillyard notes that *Chironomus zelandicus* Hudson swarms over Lake Ellesmere, New Zealand, on warm, quiet days in large vertical columns, often for hours.

Salt-water-inhabiting forms, including *Chunio murinus* Haliday, *Psammothomyia pectinata* Derby, and *Thalassomyia frauenfeldi* Schiner, live along the coasts of western Europe. The males of the Japanese *Chunio pacificus* Edwards are normally winged whereas the females are wholly apterous. It is a small maritime species only 2 mm. long. Species of the genus *Halirytus* Eaton inhabit the sea waters of Kerguelen Island in the Indian Ocean and those of *Belgica antarctica* Jacobs the oceans around Patagonia.

The family consists of some 2,000 species which are widely distributed. The

larvæ are of importance as food for small fishes and as nuisances in water tanks, reservoirs, and pipes.

Family CERATOPOGONIDÆ Malloch 1817 (Cer'a-to-po-gon'i-dæ, from the Greek *κέρας*, *κέρατος*, horn, + *πώγων*, beard; referring to the hairy antennæ). German, Gnitzen. Biting Midges, Punkies, No-see-ums, Sand Flies.

Minute species from 0.6–5.0 mm. in length, usually somber-colored. Head small, rounded or hemispherical. Antennæ slender, hairy, 13- to 15-segmented, the last three to five segments lengthened, the apical one microscopic. Ocelli absent or atrophied. Mouth parts piercing. Thorax without metanotal groove. Wings rather narrow, naked or hairy, with few veins, folded flat over abdomen at rest; alulæ slender. Femur sometimes swollen and spined beneath; plumed empodia and simple pulvilli present or absent. Male genitalia exerted; ovipositor small. Larvæ somewhat similar in general appearance to those of midges; not well known; terrestrial, subaquatic, and aquatic. They are associated with decaying vegetation, and terrestrial forms live in moist humus soils, under bark, in oozing sap, and in tree holes. Aquatic larvæ inhabit fresh, brackish, and salt water and occur in tree holes, in inland salt lakes, and in tidal pools along the seashore. The adults pierce and suck blood from other insects and from mammals and are exceedingly annoying to man. Because of their small size, they are difficult to screen out of dwellings and to keep away from the person. When numerous they swarm over the body and attack *en masse* and no exposed portions escape their onslaughts. One of the smallest species is *Brachypogon vitiosus* Winn. of Europe, 0.6 mm. long. The largest species, 2–5 mm. long, belong to the genus *Palpomyia* Meigen.

The family is relatively small but is widely distributed. Known aquatic genera are *Bezzia* Kieffer, *Culicoides* Latr., and *Forcipomyia* Meigen (in part). Other important genera are *Dasyhelea* Kieffer, *Ceratopogon* Meigen, *Lasiohelea* Kieffer, and *Leptoconops* Skuse. Members of the four genera *Culicoides*,

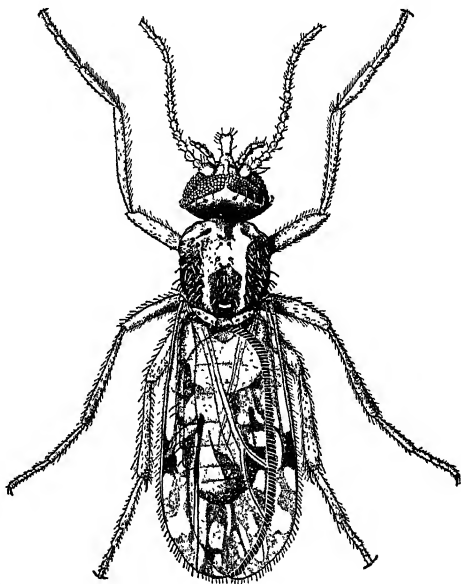


FIG. 273. The salt marsh sand fly, *Culicoides dovei* Hall, one of the biting midges or ceratopogonids. (Redrawn from Dove, Hall, and Hull, 1932.)

Ceratopogon, *Lasiohelea*, and *Leptoconops* are the most annoying to man. *Leptoconops irritans* Noe, of southern Europe, *L. americanus* Carter, and *L. torrens* (Townsend) of southwestern and western United States are all very pestiferous at certain times in spring and early summer, as are also *Culicoides guttipennis* (Coq.) and *C. stellifer* (Coq.) of eastern and southern United States; *C. molestus* Skuse, the sand fly along the coast of New South Wales; *C. obsoletus* (Meigen) in northern North America; and *C. furens* Poey, the intermediate host of the filaria worm, *Mansonella ozzardi* (Manson), which is transmitted to man in tropical America.

Certain species including *Pterobosca latipes* Edwards and *P. fidens* Edw. of China and *Forcipomyia* (*Lasiohelea*) *interpida* Edw. of Peru attach themselves to the wings of dragonflies, and *F. (Lasiohelea) tipulivora* Edw. of Dutch New Guinea is parasitic on the bodies of a crane fly, *Tipula* sp. Other species have similar habits.

d. Series ZYGOPHTHALMA Enderlein 1912

Family CECIDOMYIIDÆ Macquart 1838 (Cec'i-do-my-i'i-dæ, from the Greek *κηκίς*, *κηκίδος*, a gallnut, + *μύια*, fly; referring to the small galls produced by these small flies). German, Gallmücken. Gall Midges, Gall Gnats.

Minute to small, fragile, slender, somewhat hairy flies with long slender legs. Head small. Antennæ long, slender, moniliform, 10- to 36-segmented; segments pointed or sessile, with small bead-like swellings, prominent whorls of hairs; the males with looped and twisted filaments called *circumfili*. Eyes small, circular or reniform. Ocelli usually absent, only rarely present. Proboscis short or longer than thorax. Palpi one- to four-segmented. Wings broad; hairy or scaly; hyaline or spotted; with three to five longitudinal veins, few branches, and faint or no cross veins; one basal cell. Halteres usually well developed, hairy. Coxæ short. Tibial spurs absent. Pulvilli and empodia present. Claws simple or toothed. Abdomen eight-segmented; hypopygium may be exserted; ovipositor protractile or exserted, short or long, tip may or may not be chitinized. Larvæ white, yellow, orange, or red in color; spindle-shaped or blunt posteriorly; 13-segmented; head greatly reduced; with or without chitinized sternal thoracic *spatula* or breastplate which may be pointed; toothed or bilobed. They have a variety of feeding habits which may usually be classified as follows:

Predacious — feeding on aphids, mites, coccids, barkbeetles. Examples: *Arthrocnodax occidentalis* Felt and *Mycodiplosis acarivori* Felt predacious on orchard mites and red spiders; *Aphidoletes meridionalis* Felt on aphids; *Cecidomyia erii* Felt and *Dicrodiplosis californica* Felt on coccids; and *Itonida hopkinsi* Felt on larvæ of barkbeetles. All North American.

Saprophagous — feeding upon decayed vegetation, bark, dead wood, dung, and fungi. Including the genera *Bryocrypta* Kieffer, *Camptomyia* Kieffer, *Colomyia* Kieffer, *Colpodia* Winnertz, *Holoneurus* Kieffer, and many others.

Phytophagous — forms feeding on living plant tissues including:

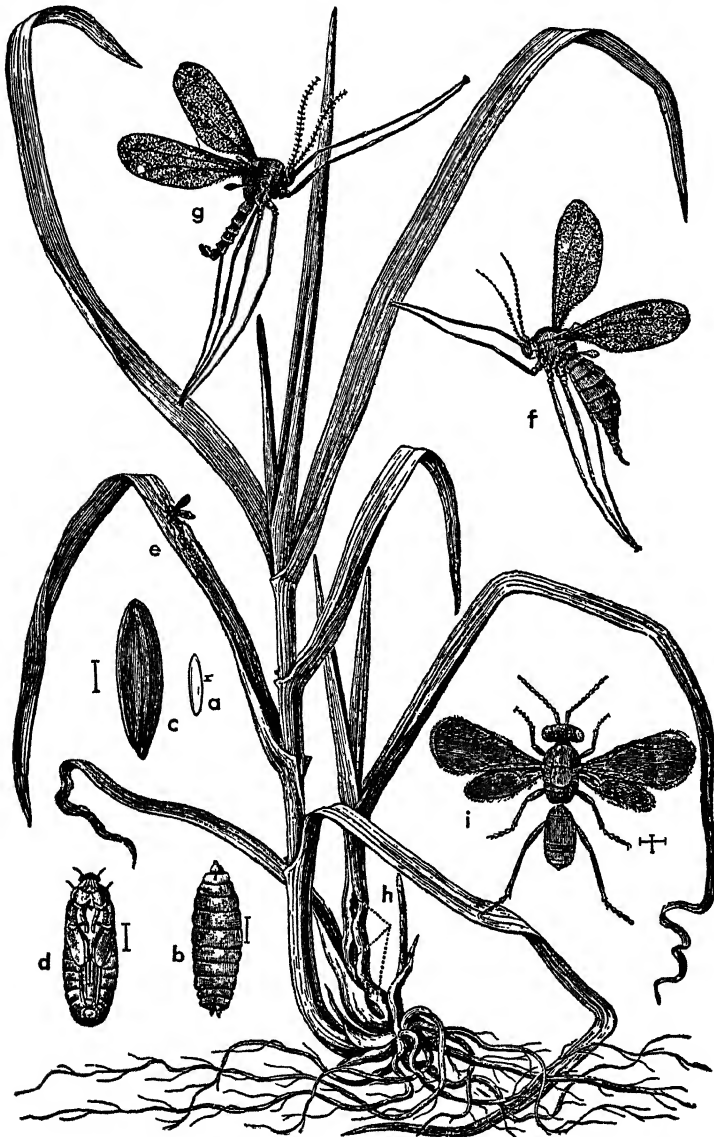


FIG. 274. An early illustration of the Hessian fly, *Phytophaga destructor* (Say). a, egg; b, larva; c, puparium or "flax seed"; d, pupa removed from puparium; e, female ovipositing on wheat leaf; f, adult female; g, adult male; h, position of larvæ and pupæ on the wheat plant; i, adult chalcid parasite, *Merisus destructor* (Say), of same. (After Packard, U.S. Ent. Comm., 1880.)

(1) Free-living larvæ which feed in the stems, flowers, fruit, and other parts of the plants. The most important species is the **Hessian fly**, *Phytophaga destructor* (Say), which originated in Asia and was introduced with hay or cereals into Europe and eventually into North America by the Hessian soldiers during the Revolutionary War about 1779. It reached the Pacific coast previous to 1884. As a pest of wheat it has few contenders and has been especially destructive in the northern United States and southern Canada east of the Rocky Mountains. The larvæ live and feed on the stems beneath the leaf sheaths and kill the plants. It has two or three generations a year. The **pear midge**, *Contarinia pyrivora* Riley, which oviposits in the flowers of pear trees and whose larvæ develop in the young fruit in North America and Europe, is a serious pest in many localities, as are also other similar species on grapes. *C. gossypii* Felt, the **cotton flower lint maggot**, is important in the West Indies.

(2) Leaf-rolling larvæ like *Dasineura rosarum* Hardy (*Dasyneura*) on peach and *D. pyri* Bouché on pear in Europe, the **violet midge**, *Contarinia violicola* (Coquillett), on violet in eastern United States, and many species on wild plants.

(3) Inquilines in the galls of other insects as *Phænolauthia cardui* Kieffer which inhabits the galls of a trypetid fly on thistles in Europe.

(4) The gall makers which produce galls of various shapes and sizes in the flowers and on the leaves, stems, and roots of many plants, but which particularly infest the species of the plant families GRAMINEÆ, SALICACEÆ, and COMPOSITÆ.

Some other rather important economic species are: The **chrysanthemum gall fly**, *Diarthronomyia hypogæa* (F. Löw), which produces small galls in the flower heads and leaves of cultivated chrysanthemums. The **sorghum midge**, *Contarinia sorghicola* (Coquillett), which feeds on the seeds of sorghum in southern United States. The **wheat midge**, *Thecodiplosis mosellana* Gehin (= *tritici* Kirby), a pest of wheat in Europe and North America. The **rice midge**, *Pachydiplosis oryzae* Wood Mason, a very serious pest of rice in Indo-China and Japan. The **clover flower midge**, *Dasineura leguminicola* (Lintner), the larvæ of which destroy the flowers and seeds of clovers in parts of western Europe and North America.

Pupation takes place in single or double cocoons or in a puparium in the galls of the host or other habitat of the larva or in the soil.

The members of the very interesting genus *Miastor* Meinert which are widely distributed have been the object of much study because of the phenomenon of pädogenesis in the metamorphosis of the species *M. metralos* Meinert of Europe and *M. americana* Felt of North America. At certain times four or five large eggs develop in the females which hatch into large larvæ. These consume the body of the mother, and very shortly each gives birth to from seven to 30 daughter larvæ which may in turn produce several successive generations of larvæ. At intervals in this succession some larvæ pupate and develop into mature sexes which mate and repeat the process. A similar phenomenon also occurs in the genus *Oligarces* Meinert of Europe (Imms, 1934).

This family contains some of the smallest species in the order, which measure scarcely more than 0.5 mm. in length and have a wing expanse of hardly more than 1.0 mm.

II. Suborder BRACHYCERA Brauer 1880

e. Series HOMÆODACTYLA Brauer 1883

Family STRATIOMYIDÆ ¹ Latreille 1802 (Strat'i-o-my'i-dæ, from the Greek στρατιώτης, a soldier, + μύα, a fly; referring to the brightly colored adults). German, Waffnenfliegen. Soldier Flies.

Small to medium-sized, bare or only slightly pubescent, dull or metallic, and often conspicuously banded or spotted with white, yellow, red, or green; body somewhat flattened. Head short and usually wider than prothorax; often pro-

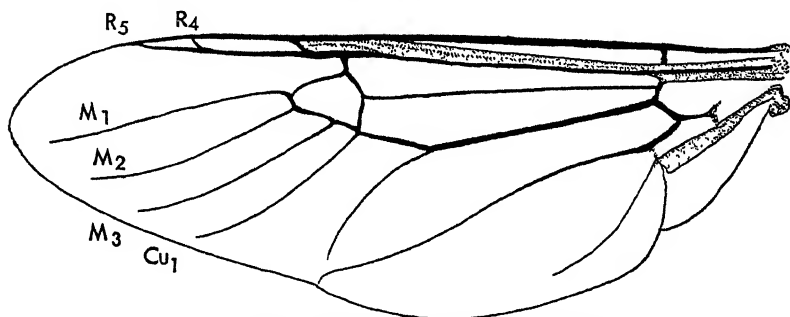


FIG. 275. Wing of the soldier fly, *Stratiomys maculosa* Loew.

duced on the frons. Eyes large, usually dioptic or holoptic in some males; bare or pilose; barred or striped. Ocelli present. Antennæ exceedingly variable; setiform or globular; geniculate or aristate; segment III annulate or furcate; arista thick or setose, one- to three-segmented, bare, pubescent, or plumose, apical or subapical. Proboscis short. Palpi rudimentary or two-segmented. Thorax usually narrower than abdomen. Prothorax may be elongated. Scutellum large, with or without spines and denticles. Wings large and narrow; transparent or partially clouded; veins in costal area heavy; costal vein not extending beyond tip; small discal cell, four or five posterior and one or two submarginal cells present; squamæ minute. (Female of the Australian *Boreoides subulatus* Hardy wholly apterous [Tillyard, 1926].) Legs with very few hairs; tibiae spurless; hind femora may be thickened; pulvilli and empodia pad-like. Abdomen flattened, wide or slender; five- to seven-segmented; may be constricted or petiolate; often brightly striped and spotted.

Larvæ variable; elongated, cylindrical, or flattened; integument may be

The family name is derived from the original generic name *Stratiomys* Geoffroy 1764 and not the emended *Stratiomyia* of authors.

segments followed by from three to eight fused annuli or terminal segments. Mouth parts for piercing and sucking; maxillæ broad cutting blades; maxillary palpi two-segmented, foliate and hairy; mandibles strong, lance-like; labium or proboscis straight, short and stout or long and slender. Thorax large, often pubescent. Wings large, hyaline or infuscated; two submarginal and five posterior cells, basal cell large, anal cell usually closed; costal vein encircling the wing; squamæ large. Legs stout, smooth or hairy; tibiæ normal or dilated, middle tibiæ two-spurred, hind tibiæ with or without spurs; pulvilli and empodia present. Abdomen pubescent, broad, inflated or depressed; seven visible segments. Genitalia hidden. Eggs slender in overlapping series in masses and covered with cement. They are often heavily parasitized by the small scelionid wasp, *Phanurus emersoni* (Girault), in North America. Larvæ rarely terrestrial, more often subaquatic and aquatic; spindle-shaped; 11-segmented excepting the small head, segments well defined and each with a raised ring useful in locomotion.

The adults are strong fliers and are to be found abundantly in lowlands and mountains in the neighborhood of water. Some forms appear content to feed upon the nectar of flowers and exudations of plants, but all of the well-known species are bloodthirsty and voracious biters, being able to puncture the thick skins of horses and cattle in a very few seconds and to cause an abundant flow of blood upon which the females become engorged. Warm-blooded animals including man are subject to their persistent and unrelenting attacks. Certain species distribute diseases such as anthrax among cattle and sheep, others transmit the trypanosomes causing the serious horse disease known as surra. Deer-



FIG. 277. Egg masses of the western horsefly, *Tabanus punctifer* Osten Sacken, on undersides of olive leaves overhanging an irrigation ditch. (From *Insects of Western North America*.)

flies, *Chrysops*, are believed to transmit tularæmia to humans in western North America. African species of *Chrysops* and other genera are essential hosts and disseminators of *Loa loa* (Guyot 1778), a parasite of man.

The family includes about 2,500 species which are chiefly tropical and subtropical, but many occur in the temperate regions. In North America, Stone (1938) lists 11 genera and 154 species. In size they vary from the smaller species of *Chrysops* and *Silvius*, 7–10 mm. long, to such species as *Straba sudetica* (Zeller) and *Tabanus intermedius* Egger of Europe, 22 mm. long, and *Therio-*

plectes gigas Herbst of Europe and *Erephopsis guttata* Donovan of Australia, both of which are 23 mm. long; and the North American *Tabanus americanus* Foster, 25–30 mm. long.

The most important genera are *Chrysops* Meigen (cosmopolitan); *Hæmatopota* Meigen (Holarctic); *Oscra* Walker (Neotropical, Australian); *Straba* Enderlein (Palæarctic); *Stenomyia* Brennan (Nearctic); *Sziladymus* Enderlein (Palæarctic); and *Tabanus* Linn. (cosmopolitan), the largest genus, with no less than 200 species in North America, 112 in Australia, eight in New Zealand, and a very great many in Africa.

The commonest North American species are *Chrysops coloradensis* Bigot, *C. nigra* Macquart, and *C. vittata* Wied. in the northern and eastern parts; and *C. surda* O.S. and *C. noctifera* O.S. in the west. The black horsefly, *Tabanus atratus* Fab., 20–28 mm. long, in the east, and *T. punctifer* O.S. in the west are the familiar large black horseflies having the thorax pubescent, whitish or yellowish in color. Species that are particularly pestiferous are *Tabanus nigrovittatus* Macq. along the Atlantic and Gulf, *T. sulcifrons* Macq. of the middle states, and *T. punctifer* O.S., *T. septentrionalis* Loew, *T. sonomensis* O.S., and *T. rhombicus* O.S. of the western states (Sloane 1938).

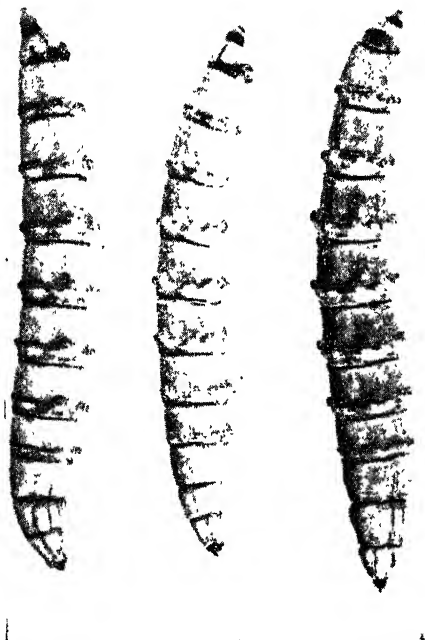


FIG. 278. Larvæ of the western horsefly, *Tabanus punctifer* O.S., taken from the mud of a fresh water pond. (From *Insects of Western North America*.)

Family ACROCERATIDÆ¹ (Leach 1815, 1819) (Ac'ro-ce-rat'i-dæ, from the Greek ἄκρον, end, tip of, + κέρας, κέρατος, horn; referring to the very long proboscis of some species). German, Spinnenfliegen. Small-headed Flies, Humpbacked Flies, Bladder Flies, Spider Flies.

Small to medium-sized flies averaging from 7–10 mm. in length; usually pilose, rarely naked; somber, brightly colored, or metallic green, blue, and golden. Head very small, low, and almost hidden. Eyes holoptic or nearly so in both sexes; bare or pilose. Ocelli, usually two or three, present. Antennæ two- to three-segmented; third small or large; apical arista absent or present; apical bristles may occur. Proboscis rudimentary or longer than the body.

¹ CYRTIDÆ or ACROCERIDÆ of authors.

Palpi absent or present. Thorax large, globular; scutellum large. Wings normal or rarely with costal extrusion; hyaline or fuscous; venation variable, weak or well defined; costa terminating at wing-tip. Squamæ large, bag-like. Legs normal; empodia and pulvilli pad-like. Abdomen almost globular with narrow base and pointed apex. The first-stage or primary larvæ are caraboid, distinctly segmented, with numerous spiny plates and two long anal bristles. They are very active and seek out spiders and their eggs upon which to feed. After they have become attached to the body of spiders, they transform into indistinctly segmented eruciform sluggish maggots and eventually into free pupæ with much enlarged thorax and many dorsal bristles. The adults are active on the wing; many hover and make a loud buzzing noise. From the long proboscis it would appear that certain forms may feed upon the nectar of flowers.

The family is a small one, consisting of some 200 species which are most abundant in the temperate regions. The important and most widely distributed genera are *Acrocera* Meigen, *On-*

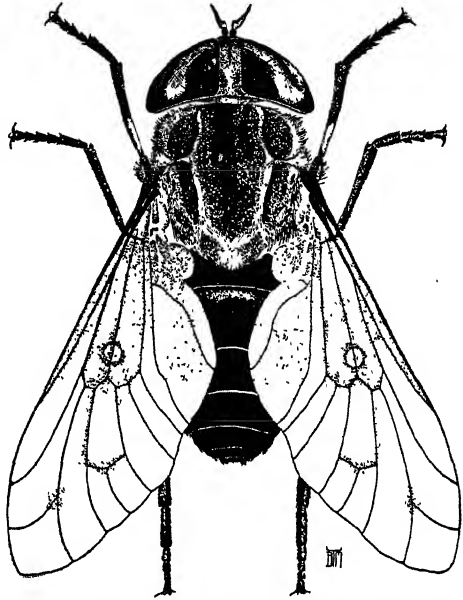


FIG. 279. The western horsefly. (After Woodworth.)

codes Latr., and *Pterodontia* Gray. *Eulonchus sapphirinus* O.S., 9–11 mm., is a beautiful metallic blue and pilose California species in which the proboscis projects beyond the tip of the abdomen. *E. smaragdinus* Gerstæcker, 8–12 mm. and metallic green, also of western United States, has even a longer proboscis. *Panops baudini* Lam. of Australia, brown with fuscous wings, is 17 mm. long and has a wing expanse of 32 mm. *Helle longirostris* Hudson, also of Australia, is a slender wasp-like fly.

f. Series *HETERODACTYLA* Brauer 1883

Family RHAGIONIDÆ¹ Bezzi 1903 (Rhag'i-on'i-dæ, from the Greek *ῥαγίων*, a poisonous spider; because of their long legs and possible resemblance to spiders). Snipe Flies.

Small to medium-sized, slender or rather stout, long-legged flies which have the body tapering posteriorly; naked or pubescent; dull or with bright spots and markings. Head small. Eyes large, circular; facets uniform or

¹ Also commonly known as LEPTIDÆ Westwood 1840.

lower ones smaller, males holoptic or dichoptic. Scutellum bare or hairy. Tibiæ with or without spurs; fore pair with one, two, or none; hind pair with one or two. Pulvilli present. Empodia vestigial, narrow or pad-like. Wings hyaline or with fuscous spots; venation distinct; usually five (rarely four) posterior cells; discal cell present or absent; costa extending around tip of wing; *r-m* distinct; squamæ absent or present, sometimes vestigial. Larvæ variable with small, partially exerted head which is prolonged in *Xylophagus*; maxillary palpi well developed; mandibles long, vertical, protrusile, simple or hooked; body 11-segmented and with pseudopods. Aquatic forms flattened and

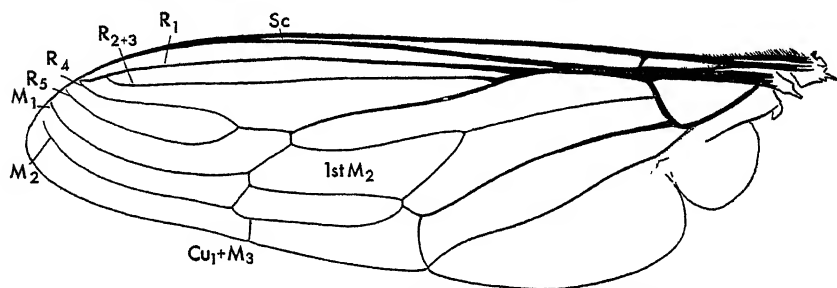


FIG. 280. Wing of the large apiocerid fly, *Raphromyia mellifex* Townsend.

with two round protrusile blood gills on the last segment below the long anal filaments. Terrestrial forms generally cylindrical; with simple or spines pseudopods on the fifth or on each abdominal segment; lateral spine-like filaments sometimes present; segments X and XI each with a row of hooklets in *Vermileo*; last segment with hairy process; spiracles present. These flies frequent wooded areas near fresh water. Aquatic forms inhabit fresh water and are predacious on small aquatic animals. Terrestrial species are likewise predacious and live under bark of trees, in dung, fungi, soil, and wood. Members of the remarkable genus *Vermileo* excavate conical pits in the sand and dust at the bottom of which they lie concealed to capture and feed on the ants that they entrap in much the same manner as ant lions. That two widely separated groups of insects with such amazing structural differences should occupy exactly the same niche in nature is remarkable. Especially is it astonishing that such a simple, helpless-looking creature as this fly larva should simulate the accomplishments of so well-equipped, active, and formidable a gladiator as is the ant lion. The larvæ of the so-called worm-lions, *Vermileo*, construct smaller and steeper sloping pits than those of their rivals, but they are often very numerous. In the protected side of a giant granite boulder in the Yosemite Valley, Calif., the author counted upwards of a thousand of these contiguous pits. The Sierra worm-lion, *Vermileo comstocki* Wheeler, occurs in the Sierra Nevada Mountains at an altitude of 4,000 to 9,000 ft.

Members of the genera *Lampromyia* Macquart and *Vermiligris* Wheeler are closely related to *Vermileo*, and the larvæ and adults are quite similar in habits and appearances. Species of *Lampromyia* have been taken in most of the Span-

ish peninsula and a small part of northern Africa in parts of Morocco, Algeria, and Tunis whereas those of *Vermitigris* occur in parts of Sumatra and Borneo. Species of the genera *Atherix* Meigen, *Rhagio* Fab. (= *Leptis* Fab.), *Spaniopsis* White, and *Symphoromyia* Frauenfeld include blood-sucking species which are often very annoying to humans. *Atherix longipes* Bell. (Mexico); *A. variegata* Walker; *Rhagio scolopacea* (Linn.) 13 mm. (Europe, North America); *R. strigosa* Meigen (Europe); *Spaniopsis longicornis* Fergusen, 6 mm. (Australia); *Symphoromyia atripes* Bigot, 5.3–8.0 mm. (western North America); *S. hirta* Johnson, 6.0–7.5 mm. (Rocky Mountain states); *S. kincaidi* Aldrich 5.5–6.0

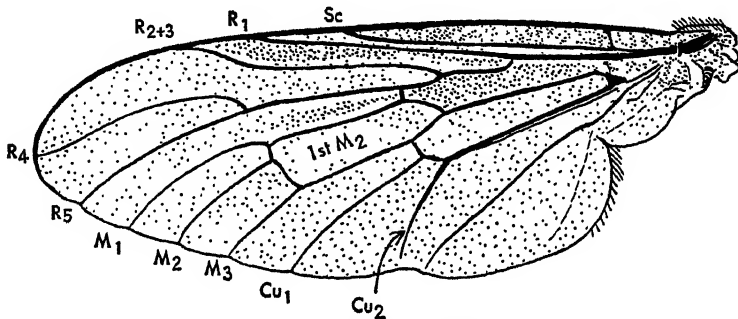


FIG. 281. Wing of *Rhagio* sp.

mm. (Pacific coast), *S. pachyceras* Williston, 6–7 mm. (western North America) are all fierce biters. The last is specially annoying in parts of the Sierra Nevada Mountains in California at high elevations (Essig, "Some Vacation Biters," *Pan-Pac. Ent.* 4:185–186, 1928).

Nonbiting species occur in some of the above genera as well as in *Bolbomyia* Loew, *Chrysopilus* Macq., *Dialysis* Walker, *Ptiolina* Zett., and *Spania* Meigen.

Family MYDAIDÆ (Leach 1815) (My-da'i-dæ, from the Greek *μυδαίω*, to be damp, wet, dripping; because the adults frequent damp places). Mydas Flies.

A small family of large flies which are characterized by the naked or only slightly hairy bodies, wide head, four-segmented, clavate antennæ with the apical segment greatly elongated and enlarged; single ocellus, pulvilliform empodia, and complicated wing venation. The family is chiefly tropical North and South American, with nine Australian species. It contains some of the largest members of the order including the Brazilian *Mydas heros* Perty which is 52 mm. long and has a wing expanse of 85 mm. *Mydas luteipennis* Loew of Texas, New Mexico, and Mexico is a large species with brilliant orange wings that somewhat mimics the tarantula hawk, *Pepsis formosa* Say, a very formidable insect that inhabits the same area. Very little is known concerning the biology of the members, but the known larvæ and adults are predacious. The important genera are *Lampromydas* Séguy, *Mydas* Fab., *Nomoneura* Bezzi, and *Phyllomydas* Bigot.

Family THEREVIDÆ Westwood 1840 (The-rev'i-dæ, from the Greek *θηρέειν*, to hunt; referring to their hunting predacious habits). German, Stilett-fliegen. Stiletto Flies.

Medium-sized to large, terrestrial, pilose or bristly flies resembling the robber flies. They are characterized by having the antennæ three-segmented, the apical segment often much enlarged and terminating in a short, slender, simple or segmented style. Proboscis large with fleshy labella and two-segmented palpi. Eyes large, not protruding, holoptic in many males. Ocelli present. Wings with five posterior cells, the fourth often closed; anal cell closed or narrowly opened apically. Legs slender and of medium length; empodia vestigial or absent; pulvilli present. Abdomen greatly elongated; male genitalia exerted, inconspicuous; ovipositor encircled with spines. Larvæ long, slender, cylindrical; head well developed but small; body 19- to 20-segmented; amphipneustic; with a pair of short anal tubercles. The larvæ live in the soil, vegetable debris, fungi, and rotten wood and are considered to be predacious. When disturbed they wriggle energetically. The pupæ are free and have setiform antennæ and body spines. The adults frequent dry meadows, sandy stretches, and woodlands, are predacious, and appear in greatest numbers during the hot season. They vary from 5-12 mm. in length.

The family is a small one consisting of some 350 species. It is well represented in the temperate regions. The genera *Tabuda* Walker and *Thereva* Latr., are common to Europe and North America.

Family BOMBYLIIDÆ Van der Wulp 1877 (Bom'by-li'i-dæ, from the Greek *βομβυλῖος*, an insect that hums or buzzes, a bumblebee; because of their resemblance to bees). German, Wollschweber. Beeflies, Bombylids.

Small to medium-sized, robust and bee-like or slender and wasp-like, downy or hairy flies which are rapid and alert fliers and often hover in the air; colors somber, variegated, bright, and metallic green, silver, and other colors. Head small, hemispherical. Eyes large; males often holoptic, females rarely so. Ocelli present. Antennæ porrect; short or long, rarely small; three-segmented; style small, one- or two-segmented, or absent, and may be replaced by a circle of bristles. Proboscis short or long and slender, labella wide. Thorax humped or slightly convex. Legs slender, weak; without bristles; pulvilli normal, minute, or vestigial; empodia usually absent; claws small. Wings well developed; clear or infuscated (pictured); venation reduced, one to four submarginal cells, discal cell rarely absent, anal cell closed or with narrow opening. Squamæ distinct, small. Abdomen wide or slender, depressed or robust; six- to eight-segmented.

The primary larvæ active, elongated, slender, and legless when first born; with hypermetamorphosis; mature forms maggot-like; metapneustic and amphipneustic; parasitic or predacious on the eggs of grasshoppers and beetles, the larvæ of bees and wasps, and the pupæ of tsetse flies, also on cutworms, army worms, and other caterpillars; and some are thought to live as inquilines in nests of bees and wasps. The pupæ are free, and those of certain predators are

equipped with chitinous anterior spines and rings of back-pointing body spines to assist them in escaping the clay and wood cells of their hosts.

The adults greatly resemble bees and wasps, are very swift fliers and darters, and often make a loud buzzing noise when captured. They frequent damp or wet places and alight on soil or rocks in close proximity to water. Certain forms visit flowers for nectar and pollen. The eggs are dropped in the close vicinity of or placed about the nests or cells of bees and wasps. The very young larvæ make their way into the cells of bees and wasps and attach themselves to the larvæ which are slowly but surely sucked dry. The admirable story of the anthrax fly, *Argyramæba trifasciata* Meigen (*Anthrax*), predacious on the wall bee, *Chalicodoma muraria* Retzius, in France, as told by Fabre, should be read by every student of entomology and everyone interested in natural history.

The large beefly, *Bombylius major* Linn., 7–12 mm. long, clothed in dense white, yellow, or brown pile intermixed with black and having the anterior

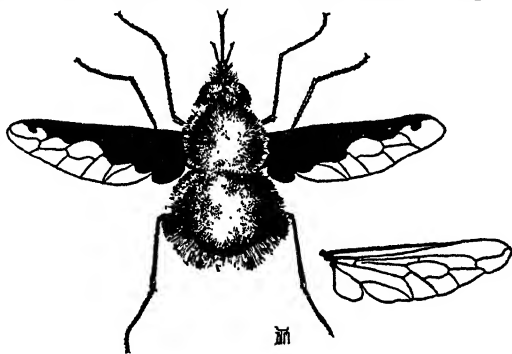


FIG. 282. The large beefly, *Bombylius major* Linn. (After Woodworth from *Insects of Western North America*.)

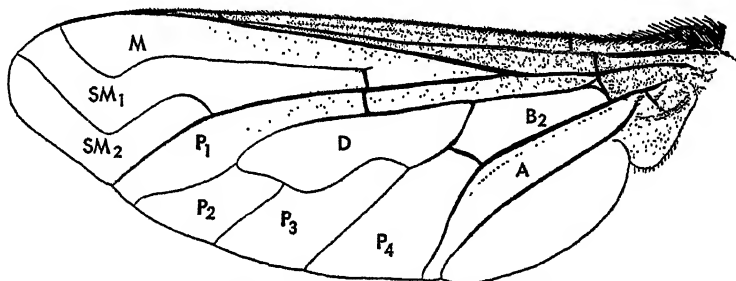


FIG. 283. Wing of the beefly, *Anthrax* sp.

halves of the wings black, is a widely distributed European, Asiatic, and North American species which is parasitic on the larvæ of bees of the genera *Andrena*, *Colletes*, and *Halictus*. The larvæ of *Aphæbantus mus* (O.S.), 8–9 mm., and *Systæchus oreas* O.S. were reported by Riley as feeding on the eggs of migratory locusts in western North America, while the larvæ of the common *Anthrax edititia* Say, 12 mm., of southern United States and Mexico are parasitic on the ground-nesting bees of the genus *Anthophora*. *Anthrax molitor* Loew is parasitic on the chrysalis of a cutworm in the southwestern states; *Hemipenthes morio* Linn., 12 mm., on the larvæ of the ichneumon, *Banchus*

femoralis Thomson, in Europe; and *Spogostylum anale* (Say) is recorded by Shelford as parasitic on the larvæ of the tiger beetle, *Cicindela scutellaris* Say var. *lecontei* Hald. in middle United States. The common *Systæchus platyurus* Walker has a proboscis 7 mm. long (Tillyard). The larvæ of *Thyridanthrax abruptus* Loew and six other species of the same genus, as well as those of *Villa lloydi* Austen of Africa are parasitic on the pupæ of the tsetse fly, *Glossina morsitans* Westwood (Neveu-Lemaire 1938).

There are about 1,800 world species in the family.

Family ASILIDÆ (Leach 1815, 1819) (A-sil'i-dæ, from the Latin *asilus*, a gadfly, horsefly). German, Bremsen. Robber Flies, Assassin Flies.

Small to the largest among flies, measuring from 5–50 mm. in length and some very robust; elongated and slender; usually downy, hairy, or bristly, rarely bare; somber black, gray, yellowish, brownish, reddish, and combinations of these colors. Head much wider than long, free, with frontal bristles and small neck. Antennæ projecting forwards; simple; normally three-segmented, the last segment elongate with a terminal thickened one- to two-segmented style or

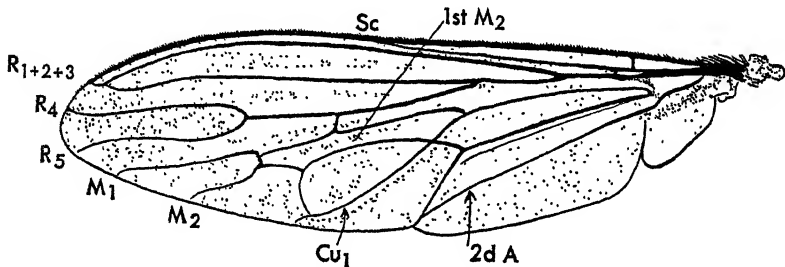


FIG. 284. Wing of the robber fly, *Asilus occidentalis* Hine.

an arista which is rarely plumed; style and arista may be absent. Eyes large, separated. Ocelli present, usually on a prominence or tubercle. Mouth parts consisting of a stout, stiff, short, horny proboscis directed downwards; labella slender; palpi two-segmented, basal segment small and the two often fused. Thorax large, convex, bristly. Legs strong, normally long and slender, bristly; femora and posterior tibiae may be enlarged; empodia present or absent; pulvilli normal, vestigial, or absent. Wings large, strong, long; clear, whitish, or fuscous; basal cells long; two to three submarginal cells; four to five posterior cells; first, fourth, and anal cells open or closed. Abdomen eight-segmented; male with prominent hypopygium; female with pointed ovipositor. Larvæ active, cylindrical or nearly so; distinctly segmented; usually pale; thoracic segments each with two long latero-ventral hairs; terminal segment variable.

The adults are predacious and capture their prey largely on the wing. They occur in woods, open fields, swamps, shores of streams and ponds, and on rotten logs, and are rapid, steady fliers resembling bees not only in appearance but in the noises produced in flight. All kinds of small active insects fall prey to these

hawkers. The larvæ are also thought to be predacious upon the larvæ of insects living in the soil, vegetable debris, litter, and in rotten wood. As a whole the members are of little economic importance. Certain species destroy considerable numbers of honeybees and at least the American species *Asilus barbatulus* Fab. and the widely distributed *A. crabroniformis* Linn., 22 mm., are occasionally known to bite humans (Neveu-Lemaire 1938).

The family consists of about 4,000 species widely distributed throughout the world. Among the most important genera are *Asilus* Linn. and *Laphria* Meigen (*Dasyllis* Loew) which are almost cosmopolitan, *Cyrtopogon* Loew (Holarctic), *Diogmites* Loew, *Erax* Scopoli, *Leptogaster* Meigen, and *Promachus* Loew (North American). One of the largest members is *Phellus glaucus* Walker, 50 mm. long, 85 mm. expanse, a steel-blue Australian species. According to Tillyard (1926), the finest of all asilids is the Australian *Blepharotes coriarius* Wied., 35 mm. long, 75 mm. expanse, black with orange abdomen decorated with black and white tufts of hair and with smoky wings. Genera that mimic bees and wasps are *Lapria* Meigen, *Mallophora* Macquart (North American), and the species *Promachus bomboides* Wied. of southern or tropical North America.

IV. Suborder GEPHYRONEURA Enderlein 1936

Family EMPIDIDÆ (Latreille 1804, 1809) Fallén 1817 (Em-pid'i-dæ, from the Greek ἐμπίς, a mosquito, gnat). German, Tanzfliegen. Dance Flies, Empids.

Minute to small species from 2–11 mm. in length; mostly slender; bristly; somber-colored, black, gray, yellowish, brownish, and a few metallic. Head small, globular, with small neck. Eyes large, holoptic in males. Ocelli present. Proboscis short or long, rigid, sharp, and piercing. Antennæ directed forwards; two- to three-segmented, first and second segments very small, apical style or arista present or absent. Thorax short or long, strongly convex dorsally. Legs slender; fore pair raptorial in one subfamily; femora or tibiæ may be bare or thickened, spined, scaled, or tuberculate; pulvilli and empodia present, the latter slender. Wings present, reduced, or absent; long with simple, abbreviated, and variable venation. Squamæ small. Abdomen seven-segmented; *Hilara* Meigen of New Zealand has lateral air floats; male genitalia enlarged and intricate; female may have long, awl-like, chitinized ovipositor. Larvæ slender, cylindrical or spindle-shaped, with small head and 11 body segments; amphipneustic; pseudopods may be present; body terminated by spine or tubercle and a pair of spiracles. They are predacious upon small arthropods and are either terrestrial, living in the soil, moss, vegetable debris, dead wood, and under bark, or are aquatic, living in fresh water. Aquatic larvæ are known to occur in the genera *Hemerodromia* Meigen of Europe and North America and *Ræderioides* Coquillett of North America. In size these flies vary from the European *Ragas unica* Walker, 1.75 mm. to the New Zealand *Hilara flavinceris* Miller, 11 mm. in length.

The adults get the name "dance flies" from their mating reactions which

consist of swarms (*Empis*, *Hilara*, *Rhamphomyia*, and other genera) that move up and down over the surface of land and water. They are predacious on small insects and other invertebrates, and some are bloodsuckers. There are a number of accounts of the interesting courting reactions of males of a number of species which offer newly captured prey to the female. Those of *Hilara* have the basal segment of the fore tarsi¹ enlarged and functional as a spinning gland from which many threads of silk may be drawn to make webs or balloons to capture living prey which is offered to the female. In Europe Eltringham (1928) has listed eight species of *Hilara*, the males of which spin silk as indicated. The commonest of these is *H. maura* Fab. whose habits are described by Hamm (1928). *Empis aërobatica* Melander of North America blows a bubble around the morsel offered the female, and *E. poplitea* Loew, also of North America, is known as the balloon-making fly. They occur in well-watered areas in woods and along streams, and a number of species visit flowers.

The most important genera are *Chelifera* Macquart (European, North American), *Drapetis* Meigen (European, North American, Australian), *Empis* Linn., *Hilara* Meigen, and *Rhamphomyia* Meig. (Holarctic and Australian), *Meghyperus* Loew and *Ragas* Walker (European), *Trichina* Meig. and *Wiedemannia* Zetterstedt (European, North American).

The family, consisting of some 1,600 species, is generally distributed throughout the world.

Family DOLICHOPODIDÆ Leach 1819 (Dol'i-cho-pod'i-dæ, from the Greek δολιχός, long, + πούς, foot; referring to the long legs). German, Langbeinfliegen. Long-legged Flies, Long-headed Flies, Dolichopodids.

Minute to small, 1–11 mm. long; slender, long-legged, and some long-headed flies; smooth; normally with bristles on the head, thorax, and legs; black, gray, or yellow and usually brilliant metallic green, blue, coppery, golden, and silvery. Males often with specially ornamented head, antennæ, palpi, wings, or legs.

Head hypognathous; wider than thorax; normal or elongated in some genera. Eyes large, holoptic in males and covering most of head. Antennæ three-segmented; arista dorsal or apical; bare or plumose in males; segment III may be elongated in males and tuberculate in females. Proboscis short, fleshy, retractile; labella large, fleshy. Thorax may be depressed in front of scutellum. Wings hyaline or clouded; venation simple; discal and basal cells confluent; sixth vein present or absent. Squamæ reduced. Legs medium to long; coxæ short; tibiæ may be modified and brightly colored; fore tarsi of male often ornamented with large dark or bright apical tufts; claws, pulvilli, and empodia small. Abdomen five- to six-segmented; variously shaped; cylindrical, conical, compressed dorsally or laterally. Hypopygium of male small and concealed or large, conspicuous, and complicated. Larvæ slender, cylindrical, 12-segmented, mostly amphipneustic with abdominal spiracles very small; head very small,

¹ Members of the order EMBIOPTERA also have the basal segment of the fore tarsi modified for spinning silken webs which are used chiefly for lining their burrows and passageways.

retractile; posterior spiracles separated and surrounded by short lobes; aquatic or terrestrial. Pupæ free.

The adults are abundant near water and occur on flowers, foliage, bark, and surface of pools. They are largely predacious on small flies and other minute insects and arachnids. Adults occurring commonly on tree trunks belong to the genera *Medeterus* Fischer and *Neurigona* Rondani (Holarctic); those on foliage

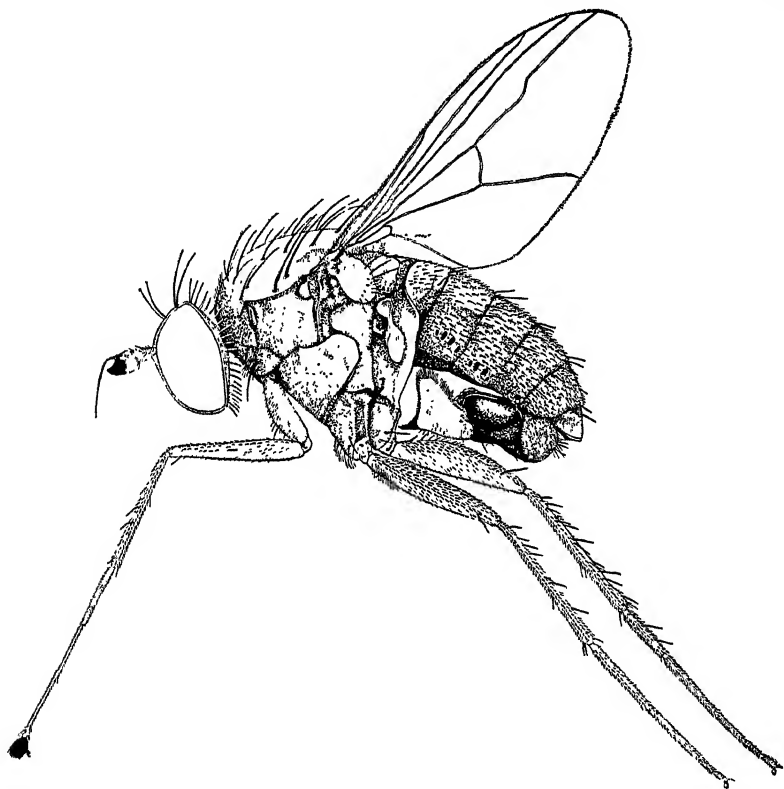


FIG. 285. A long-legged male dolichopodid fly. (From *Insects of Western North America*.)

to *Chrysotus* Meigen, *Diaphorus* Meig., and *Hercostomus* Loew (Holarctic), and *Condylostylus* Bigot (North American); those on the surface of mud and water to *Hydrophorus* Fallén and *Camptosceles* Haliday (*Campsicnemus* Haliday) (Holarctic); those which are littoral to *Epithalassius* Mik, *Glyphidocerus* Enderlein, and *Muscidideicus* Becker (Palearctic). Known larvæ living in stems of plants occur in the genus *Thrypticus* Gerstæcker (Holarctic); under bark: *Medeterus* Fischer; on spray-dashed rocks: *Aphrosylus* Walker, *Encoryphus* Mik (Europe), and *Dolichopus* Latr. (Holarctic). *Psilopus* Meigen is the largest genus inhabiting Australia and New Zealand (Tillyard, 1926).

One of the smallest species appears to be *Micromorphus albipes* Zetterstedt of Europe, 1 mm. long.

Medeterus aldrichii Wheeler is an enemy of barkbeetles, *Dendroctonus* spp., in the northwestern states.

The family contains about 2,000 species and is cosmopolitan.

B. Group CYCLORRHAPHA Brauer 1880

V. Suborder ASCHIZA Becker 1882

Family PHORIDÆ Haliday 1851 (Phor'i-dæ, from the Greek *φῶρ*, a thief; referring to the guest species in nests of ants and termites). Humpbacked Flies.

Minute to small, somber, somewhat bristly, very active flies with prominent humped thorax. Head small, free. Antennæ three-segmented, the apical segment large and often covering one or the two basal segments, arista three-segmented, subdorsal or apical. Legs moderately long and spined. Wings normal in size, abnormal in form, vestigial or absent; veins heavy in basal half of costal area, greatly reduced elsewhere. Abdomen eight-segmented. Larvæ variable, 11-segmented, pointed anteriorly and truncate posteriorly, metapneustic and amphipneustic, with papillæ arranged in bands on the segments. Pupæ enclosed in last larval skin and with a pair of respiratory horns. The adults visit flowers and foliage and buildings. The saprophagous larvæ feed on dung, vegetable debris, fungi, and carrion, particularly dead snails. Some live asinquilines in the nests of termites and ants, and still others are parasitic on various arthropods.

The family is still in a state of revision and is subject to many changes. There are perhaps 1,000 described species which are widely distributed. The genera *Aphiochæta* Brues, *Hypocera* Lioy, and *Phora* Latr. are almost cosmopolitan. *Aphiochæta agarici* (Lintner) and *A. albidihalteris* (Felt) have been reared from mushrooms, and *A. cata* (Melander and Brues) from the nests of bees, *Halictus*, in eastern United States. A number of genera, especially indigenous to South America, are myrmecophilous and termitophilous, and certain species of *Ecitomyia* Brues, *Hypocera*, *Phora*, and *Metopina* Macquart may have similar habits in temperate regions. All are more common in ants' nests. *Plastophora curriei* Malloch and *Commoptera solenopsidis* Brues are parasitic on the fire ant, *Solenopsis* sp., in western North America, and *Phora epeiræ* Brues has been reared from spider eggs in eastern United States. *Megaselia juli* Brues, common to both North and South America, is parasitic on millipeds, *Julus* spp. The wingless *Puliciphora occidentalis* Melander and Brues is recorded from the nests of *Halictus* in Massachusetts, and species of *Melittophora* Brues have been taken from the nests of the so-called stingless bees in Colombia. Members of the African genus *Wandolleckia* Cook live in the slime on the bodies of land snails in Africa.

Family TERMITOMASTIDÆ Silvestri 1901 (from Latin *termes*, a woodworm, + the Greek *μαστέω*, to seek; *i.e.*, termite seekers or guests).

Very small, nearly apterous flies living as guests orinquilines in the nests of termites in South America. They have long antennæ that appear 20-segmented, fused eyes, ocelli, and reduced wings. They are closely related to the SCIARIDÆ and belong in the suborder NEMATOCERA.

Family TERMITOXENIIDÆ Wasmann 1901 (from the Latin *termes*, a woodworm, + the Greek *ξένος*, guest; *i.e.*, guests of termites).

Highly specialized, physogastric flies with vestigial wings, swollen abdomen deflexed forwards over the thorax; arista plumose; mouth parts free; eyes small, circular; legs long. Some are thought to be hermaphroditic. They live in termite nests and excrete substances that are eagerly sought by the termites. At least two species occur in India and the East Indies.

Family THAUMATOXENIDÆ Breddin and Börner 1904 (from the Greek *θαύματος*, a wonder, marvel, + *ξένος*, guest; very remarkable guests).

Oval, dorsally depressed, wingless species which have little resemblance to flies; head large, extending back over thorax; eyes small, circular; antennæ resting in grooves and with apical arista; legs long; abdomen not visibly segmented. Two species occur in termite nests in the Mediterranean Basin.

Family BRAULIDÆ Egger 1853 (Brau'li-dæ; derivation unknown). German, Bienenläuse. Bee Lice.

Minute, wholly apterous, compact, hairy, spiny, or bristly insects which are most frequently found clinging to the head, thorax, and base of the abdomen of honeybees. The adults are white, brown, or reddish-brown. Head large, as wide as thorax. Antennæ short, hidden in a deep groove or receptacle; composed of two segments and a subapical or terminal style or arista. Mouth parts hypognathous, short. Eyes vestigial. Ocelli absent. Thorax short; indistinctly segmented. Legs large; hairy; tarsi five-segmented, terminal segment large; claws in the form of a divided comb each bearing 15 to 16 teeth; pulvilli pyriform. Abdomen with five visible and three invaginated segments. The males are slightly smaller than the females. The larvæ are muscoid in form and live in the hives of honeybees where they burrow through the comb to feed upon the honey and food of the bee larvæ. The adults ride from hive to hive on the bees, and a few to several hundred may thus be found on a single bee.

This family consists of but a single species, the bee louse, *Braula cæca* Nitzsch (1818), 1.0–1.5 mm. long, which has probably been associated with honeybees in the Old World for ages. It was first recorded in print by the famous early French entomologist Réaumur in 1740. Although the insect is often abundant in the hives of weak and neglected bees in the Mediterranean region and in eastern Europe, comparatively little is known concerning the exact biology of either the larvæ or the adults. The very small eggs are laid at random among the brood cells in the hives. The larvæ burrow from cell to cell and are

obviously unknown to the bees. According to Phillips about 20 days are required for development. The adults emerge from pupæ either in or outside the cells of the larval bees. They not only ride the bees but are considered to be annoying robbers or highly specialized ectoparasites. They are able to procure food from the bees by clawing at their mouth parts, and this and other irritations are thought to injure the hosts. Bees, especially the queens which are particularly attractive to them, appear to generally disregard them although the stronger and more active workers have been observed to rub them off their

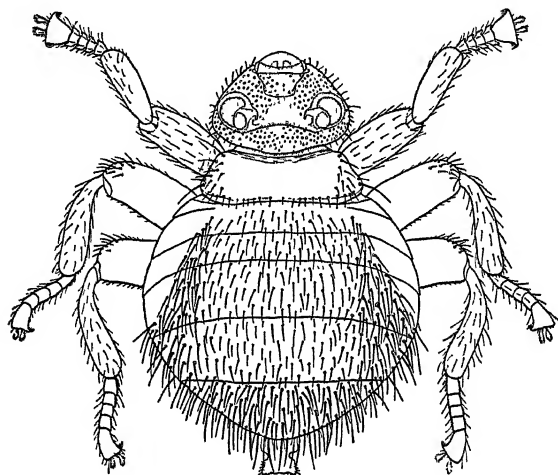


FIG. 286. The bee louse, *Braula ceca* Nitzsch, an old world ectoparasite of the honeybee rarely taken in North America. (Drawing by E. S. Ross.)

bodies. The species now appears to be most abundant in parts of southern Europe but has been widely distributed and is known to occur in parts of eastern North America, South America, Tasmania, South Africa, Japan, and possibly elsewhere. It was first noted in North America in Pennsylvania by E. H. Hess in 1918 and does not appear to have spread very rapidly. Several species have been described, but they are generally supposed to be forms of the common bee louse described above.

Family PLATYPEZIDÆ Walker 1851 (Plat'y-pezi'dæ, from the Greek πλατύς, broad, wide, + πῆξ, foot; because of the wide hind tarsi). German, Tummelfliegen, Rollfliegen. Flat-footed Flies.

The adults are small, 2-4 mm., thinly haired and bristled, somber-colored flies characterized by enlarged and flattened hind tarsi which are ornamented in some of the males. The eyes are often holoptic. Ocelli present. Antennæ three-segmented, with a long dorsal or terminal arista. Tibiæ spurless. The larvæ are wide and flattened; pale-colored; with lateral, segmented, spiniferous processes on all the segments except the first, second, and last. They live and

breed in various kinds of fungi and especially in toadstools and mushrooms, and some species are pests of the latter. The adults often appear in swarms in the air and run rapidly over the foliage of plants and on the hosts.

The family is a very small one of some 100 described species which are most numerous in the Holarctic region with representatives in other parts of the world. According to Curran (1934) there are less than 30 described species in North America. One of the most interesting species is the **European smoke fly**, *Microsania stigmatalis* Zetterstedt, which appears to be attracted in swarms to smoke. It has been introduced into New Zealand and Tasmania.

The commonest genus is *Platypeza* Meigen. *P. agarici* Willard and *P. polyptori* Willard are common in toadstools and mushrooms in western North America. The **banner fly**, *P. insignis* (Aldrich), is a common North American species with long banner-like or foliate appendages on the hind tarsi of the male.

Family SYRPHIDÆ (Leach 1815, 1819) (Syr'phi-dæ, from the Greek *σyrphos* or *σέρφος*, a small winged insect, a kind of gnat or winged ant). German, Schwebfliegen. Syrphid Flies, Flower Flies, Sweat Flies, Hover Flies, Drone Flies.

Small, medium to large, smooth or pilose, common flies which are very active on the wing, hovering and darting in the air with great agility. They are broad or slender; somber and of one color or more often marked with bright-yellow, orange, or creamy-white bars and spots; some are metallic blue, green, and brassy. Head large, some with frontal projections. Antennæ three-segmented and may arise from small or large tubercles; with style or arista. Arista usually dorsal, rarely dorso-apical; simple or three-segmented; longer or shorter than the apical segment; bare or plumose. Eyes usually dichoptic in females and holoptic in males; naked or pilose. Proboscis normally short, rarely as long as the body (in *Lycastis cornutus* Enderlein of Japan). Ocelli present. Thorax large, rarely bristly. Legs normal. Wings large; apical cell closed; anal cell large, closed before the margin; spurious vein (*vena spuria*), thought to be the vestigial M A, lying between R and M and free at both ends, is normally present and is one of the most distinctive characteristics of the members of the family; it is only rarely absent. Abdomen with four or five visible segments. Male hypopygium often large but not conspicuous. Eggs variable; some of the common ones occurring among aphids are white, elongated and reticulated. Larvæ variable, 11-segmented; amphipneustic and metapneustic, head reduced. The larvæ usually fall into one of the following four types:

1. *Limpet* or *Microdon* — oval, convex; sculptured surface; hard or leathery; with fused tubular anal spiracles and without anterior spiracles (metapneustic). Represented by the genus *Microdon* Meigen living in ants' nests and feeding on the dry pellets ejected by the ants.

2. *Short-tailed* or *Syritta*, cylindrical and robust; posterior respiratory tubes short; with or without three pairs of fleshy protuberances on the last segment; plumose hairs encircling the posterior spiracles. Represented by *Syritta* St. Fargeau and Serville and *Tropidia* Meigen.

3. *Rat-tailed* or *Eristalis*, cylindrical; slender or robust; posterior respiratory tube retractile and may be from one to three or more times as long as the body (in *Myiatropa florea* Linn., 12–15 mm. long, of Europe, the tube is 12 times the length of the body, 9 or 10 in. long); with circlet of long hairs at the apex; pseudopods on most of the body segments. Feeding in liquid vegetable extracts

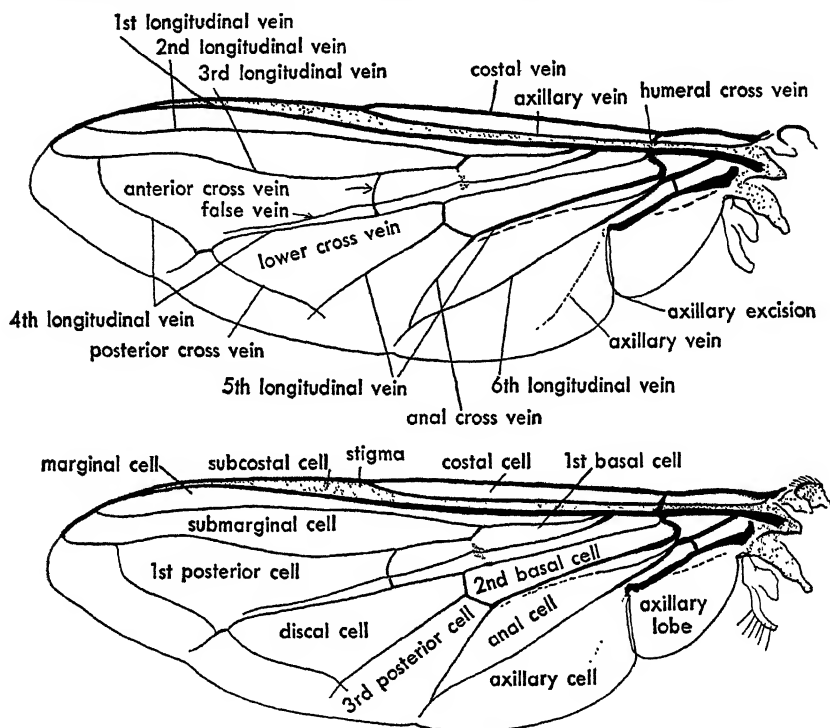


FIG. 287. Wings of the large syrphid fly, *Scæva pyrastri* (Linn.). The false or spurious vein is important in recognizing the flies belonging to the family SYRPHIDÆ.

and filth. Represented by the genera *Cheilosia* Panzer, *Eristalis* Latr., and *Eumeros* Meig. (*Heliophilus* Meig.).¹

4. *Aphidivorous* or *Syrphus*, elongated, somewhat flattened, pointed anteriorly and truncate posteriorly; posterior spiracular tubes reduced; short, soft, pointed, lateral body tubercles often present; green, brown, gray, or mottled. Predacious on aphids and coccids. Representatives in many genera include *Allograpta* O.S., *Baccha* Fab., *Melanostoma* Schiner, *Paragus* Latr., *Pipiza* Fallén, *Scæva* Fab., and *Syrphus* Fab.

The pupæ are of the primitive type, being enclosed in the last larval skin;

¹ The genera *Elophilus* and *Eumeros* were both erected by Meigen in 1803. The spelling of the former was changed to *Heliophilus* by Leach in 1817 and the latter to *Eumerus* by Meigen in 1804. Since the form *Eumeros* has page priority it is accepted here.

shortened; oval, cylindrical, pyriform, or nearly hemispherical; spiracles protruding through the larval skin, sessile or on tubes, on segments IV and V; skin ruptures dorsally to release the adult.

Members of this family are quite diverse in size, form, and habits. In size the adults vary from the widely distributed lesser bulb fly, *Eumeros strigatus*



FIG. 288. Egg of the large syrphid fly among the exuviae or cast skins of aphids. (From *Insects of Western North America*.)

(Fallén), 4–6 mm. long, to the large black and whitish New Zealand *Pilinasica cingulata* (Fab.), 19 mm. long. Members of the genera *Eristalis* and *Pocota* St. Farg. and Serv. mimic honeybees; *Cerioides* Rond. and *Syrphus*, wasps; and *Merodon*, bumblebees. The so-called **Bugonia Myth** of the ancients, the belief that honeybees were spontaneously generated in carcasses of animals, was held until only a generation ago when C. R. Osten Sacken showed that the drone fly, *Eristalis tenax* (Linn.), and related species which resemble honeybees were really the insects that developed in dead carcasses and filth.

The adults feed upon nectar in flowers and are responsible for much good in cross-pollination of agricultural as well as wild plants. Others imbibe the sap of trees and juices from decaying organic materials. The feeding habits of the larvæ are exceedingly varied, and the genera may be segregated into the following groups according to the food of the maggots:

I. Saprophagous

1. Decaying vegetation — *Tubifera* Meig.,¹ *Eumeros* Meig., *Copestylum* Macq., *Chrysotoxum* Meig.
2. Liquid filth — *Eristalis* Latr.

¹ The genus *Tubifera* Meig. is used for *Eumeros* Meig. (*Heliophilus* Meig.) and for *Eristalis* by some recent workers.

3. Scavengers or *inquilines*

- (1) In nests of ants and termites — *Microdon* Meigen.
- (2) In nests of bees and wasps — *Volucella* Geoffroy.



FIG. 289. The larva of the large syrphid fly feeding on the pea aphid. (Photo by Doten from *Insects of Western North America*.)

II. Phytophagous

1. Wood borers — *Temnostoma* Lep. and Serv., *Mesogramma* Loew, *Cheilosia* Panzer.
2. In wounds of trees — *Tubifera* Meig., *Xylota* Meig., *Myiolepta* Newman, *Cerioides* Rond.
3. On foliage of plants — *Mesogramma* Loew.
4. On bulbs — *Merodon* Meig., *Eumeros* Meig.

III. Predacious

1. On aphids

- | | |
|--------------------------------|--------------------------|
| (1) <i>Allograpta</i> O.S. | (5) <i>Pipiza</i> Fallén |
| (2) <i>Baccha</i> Fab. | (6) <i>Syrphus</i> Fab. |
| (3) <i>Melanostoma</i> Schiner | (7) <i>Scæva</i> Fab. |
| (4) <i>Paragus</i> Latr. | |
2. On coccids
- (1) *Baccha* Fab.

Accidental intestinal myiasis in humans has been produced by larvæ of *Eristalis tenax* (Linn.), *E. arbutorum* (Linn.), and *E. dimidiatus* Wied., and *Tubifera pendula* Meig. (Neveu-Lemaire, 1938).

The family is a comparatively large one for the order and consists of about 3,500 species which are cosmopolitan in distribution.

Among the common important species may be mentioned: *Baccha elongata* Fab. (European); *B. clavata* (Fab.) (North and South American).

Cheilosia antiqua Meigen (European); *C. pulchriceps* Loew (European and North American).

Eristalis æneus (Scopoli) (European and North American).

Drone fly, *Eristalis tenax* (Linn.) (cosmopolitan).

The lesser bulb fly, *Eumeros strigatus* (Fallén) (*Eumerus* Meig.), (European; a scavenger introduced into North America and elsewhere on bulbs).

The large syrphid, *Scæva pyrastris* (Linn.) (*Lasiophiticus*) (European and North American).

Melanostoma mellinum (Linn.) (European and North American).

The bulb fly, *Merodon equestris* (Fab.), (European; introduced into North America and elsewhere on bulbs).

Microdon devius (Linn.) (European); *M. tristis* Loew (North American). *Paragus bicolor* (Fab.) and *P. tibialis* (Fallén) (European and North American).

Syrphus arcuatus (Fallén) and *S. ribesii* (Linn.) (European and North American). *Volucella bombylans* (Linn.) (European); *V. esuriens* (Fab.) (North American).

The family comprises some 3,000 species.

Family PIPUNCULIDÆ (Zetterstedt 1842) Curtis, Walker 1851 (Pi'pun-cul'i-dæ, origin uncertain). Big-headed Flies.

Small, slender, somber flies with large, almost spherical heads and with enormous contiguous eyes. The antennæ may have the apical segment elon-

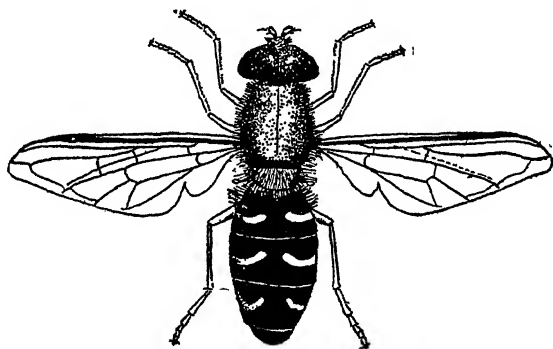


FIG. 290. The large syrphid fly. (From *Insects of Western North America*.)

gated and with a sharp apical style; long dorsal arista usually present. Ocelli present. Proboscis small. Legs without spines; pulvilli present. Wings large and with distinct veins. Females with exserted, chitinized ovipositor. The larvæ are small, pointed anteriorly, 10- to 11-segmented. Pupæ in larval skin with anterior spiracular horns and a pair of posterior spiracles. Pupation occurs in the soil or litter. The adults visit flowers, grasses, and small shrubbery, and may be seen hovering in the air. They are strong fliers and sufficiently skilled to oviposit on the active nymphs chiefly of the homopterous families FULGORIDÆ and CICADELLIDÆ. The larvæ are parasitic in the bodies of the hosts and orient themselves so that the head is in the same direction as that of the host. When mature they rupture either the dorsal or ventral integument joining the thorax and abdomen, leaving a large hole in the carcass.

The family is a small but important beneficial one and includes some 300 described species which are chiefly Palearctic. Considerable numbers of representatives are found elsewhere, but extremely few are known from tropical Africa and South America. The six common genera are *Cephalosphæra* Enderlein, *Chalarus* Walker, *Jassidophaga* Endl., *Nepherocerus* Zett., *Pipunculus* Latr. and *Verrallia* Mik. All except the first and third occur in North America. The genus *Pipunculus* is the most widely distributed and contains most of the known species, including many in Europe, about 35 in North America, three in Hawaii, four in New Zealand, and 26 in Australia. *P. campestris* Latr. is a

common European species. At least 12 species have been reared from the **beet leafhopper**, *Eutettix tenellus* (Baker), in western North America. Of these *P. industrius* Knab, *P. similis* Hough, *P. subnilens* Cresson, *P. unguiculatus* Cress., and *P. vagabundus* Knab are the most important.

VI. Suborder SCHIZOPHORA Becker 1882

g. Series ARCHISCHIZA Enderlein 1936

Family CONOPIDÆ (Leach 1815) Stephens 1829 (Con-op'i-dæ, from the Greek κώνωψ, a gnat, mosquito). German, Dickkopffliegen. Thick-headed Flies, Wasp Flies.

Small to medium-sized, 4–10 mm., unusual, elongated, and often wasp-like parasitic flies which are sluggish or active; bare, thinly pilose, or rarely slightly bristly; somber black, reddish, or brown with yellow, white, or orange markings. Head broader than thorax and with ptilinal suture. Eyes large. Ocelli present, vestigial, or absent. Antennæ porrect; arising from frontal extrusion; three-segmented, the last segment enlarged; with dorsal, subdorsal, or terminal arista

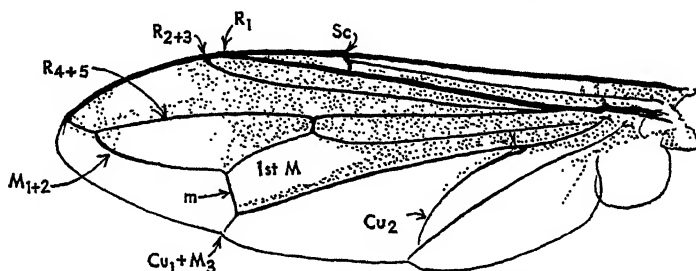


FIG. 291. Wing of the conopid fly, *Physocephala affinis* Williston.

or a pointed terminal style. Thorax somewhat humped. Wings hyaline or dusky; anal cell closed. Abdomen may be constricted at base and wasp-like or normally broad; genitalia large in both sexes and curved under body; ovipositor may be well developed and in *Stylogaster* Macquart is longer than the body. The eggs are peculiar in that they have small hooks or filaments for attaching them to the bodies of the hosts. The larvæ are highly specialized, broad, ovoid or pyriform, with reduced mouth parts and the posterior spiracles screened and with large convex plates. The pupæ are enclosed in the last larval skin and have a pair of anterior and posterior spiracles. The adults are slow or rapid fliers and some hover. They visit certain kinds of flowers, and those that have been observed strike or oviposit on the host while in flight. The newly hatched larvæ burrow into the abdominal cavities of the host, develop as endoparasites, and pupate within the carcass.

The family is a small one and contains about 500 species which are widely

distributed. The most important genera are *Conops* Linn., *Dalmannia* Robineau-Desvoidy, *Myopa* Fab., *Occemyia* R.-D. (*Oncomyia*, Loew), *Physocephala* Schiner, *Sicus* Scopoli, *Stylogaster* Macquart, and *Zodion* Latr. Species of *Conops* are parasitic on bees belonging to the genera *Bombus*, *Chalicodoma*, and *Osmia* and on the wasps *Odynerus*, *Pompilus*, *Sphex*, and *Vespa*. *Conops flavipes* Linn. is the commonest species in Europe, *C. pictus* Fab. is widely distributed in tropical North and South America, and *C. pica* Macq. is the commonest of the 12 Australian species. *Myopa clausa* Loew occurs in Europe and North America. *Physocephala affinis* (Williston) has been reared from the bee, *Anthidium emarginatum* (Say), in California.

h. Series PROTOMUSCARIA Enderlein 1936

Family SCATOPHAGIDÆ Robineau-Desvoidy 1830 (Scat'o-phag'i-dæ, from the Greek σκῶρ, σκατός, dung, + φαγεῖν, to eat; referring to the dung-feeding habits of the larvæ). Dung Flies.

The members of this family cannot be readily separated from the MUSCIDÆ, with which they are united by Curran (1934) and other specialists. The

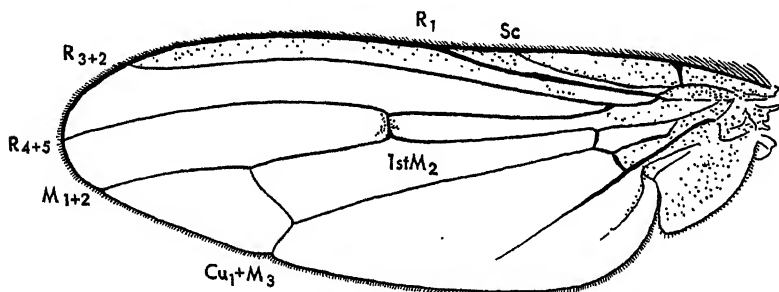


FIG. 292. Wing of the dung fly, *Scatophaga* sp.

common saprophagous genera are frequently tawny, hairy species whose larvæ live in dung and decayed vegetation and whose adults are predacious on other small flies and various insects. In this group are the genera *Scatina* R.-D., *Scatophaga* Meigen, and *Scopeuma* Meigen. Genera containing phytophagous and mostly leaf-mining species are *Clidogastra* Macquart, *Hydromyza* Fallén, and *Norellisoma* Hendel.

Members of the family CORDYLURIDÆ Macquart 1835 are closely related to the MUSCIDÆ and the SCATOPHAGIDÆ, and may be grouped with either or both of them. The larvæ are mostly scatophagous or phytophagous whereas the adults of many species are predacious. Genera containing leaf miners and root feeders are *Chylizosoma* Becker, *Cnemopogon* Rondani, *Cordylura* Fallén, *Hexamitocera* Becker, *Leptopa* Zetterstedt, *Phrosia* R.-D., *Megaphthalma* Becker, and others.

i. Series ACALYPTRATÆ Macquart 1835

Family PIOPHILIDÆ Macquart 1835 (Pi'o-phil'i-dæ, from the Greek *πῶν*, fat, + *φιλεῖν*, to love; because the larvæ feed on fats of various kinds).
Skippers, Cheese Maggots.

A family of small flies scarcely more than 5 mm. in length which are usually dark, shiny, and sometimes faintly metallic blue; with fleshy proboscis; two pairs of vertical bristles; large oral bristles; large palpi; antennæ decumbent, segment III elongate, arista bare; four scutellar bristles; mesonotum relatively naked; wings well developed, costa broken near the apex, discal cell large; abdomen pollinose but without bristles; ovipositor protrusile. Larvæ muscoid, pale, with two short fleshy anal processes not bearing spiracular plates. They are largely saprophagous. The one important species is the cosmopolitan **cheese skipper**, *Piophilæ casei* (Linn.), 2.5–4.0 mm., dark with bluish reflections, which feeds on cheese, fats, cured meats, carrion, and fungi. The maggots are pale yellowish, 8–10 mm. long, and because they jump or throw themselves about when disturbed they are called skippers.

Members of the related family PSILIDÆ Walker 1853 are small shining, slender flies of which the maggots of one member, the **carrot rust fly**, *Psila rosæ* (Fab.), an European and American species, attack the roots and crowns of carrots, parsnips, celery, and other umbelliferous plants.

Family TRYPETIDÆ¹ Loew 1862 (Try-pet'i-dæ, from the Greek *τρύπητης*, a borer, an auger; referring to the ovipositor of the females). German, Fruchtfliegen. Fruit Flies.

Small to medium-sized flies, 1.5–6.0 mm. long; slightly hairy and bristly; usually yellow, amber, brown, orange, black, and combinations of these colors. Head large, broad, and with very small neck. Occipital bristles slender and sharp or stout and blunt. Lower frontal-orbital bristles present and close to the eyes. Vibrissæ absent. Antennæ decumbent, short. Arista dorso-basal; bare or pubescent. Eyes large, frequently iridescent green. Ocelli present or absent. Proboscis short, fleshy; labella large. Oral hairs present. Thorax with anterior bristles sometimes absent. Middle tarsi spurred. Wings large; mostly pictured, rarely clear; frequently extended and moved back and forth while walking or resting; subcosta turned up sharply near apex; basal and anal cells present, the latter angular and usually pointed. Abdomen usually with four to five distinct segments. Ovipositor often prominent; three-segmented, sclerotized; longer than the body in *Toxotrypana* Gerstæcker. Larvæ muscoid; shortened when mature; anterior spiracles from 14- to 38-lobed; posterior spiracular plates contiguous, each with three long, subparallel slits.

¹ The name for this family has long been given as TRYPETIDÆ Loew 1862 from the genus *Trypeta* Meigen 1803. Curran has adopted the name TRUPANEIDÆ, which is derived from the genus *Trupanea* Schrank 1795. The latter was amended to *Trypanea* by Agassiz in 1846. Both of these family names are antedated by TEPHRITIDÆ (Newman 1845) Macquart 1835, but I am following the suggestion of Sabrosky in retaining the generally accepted designation.

The adults are visitors of flowers, fruits, and the foliage of plants. They are usually conspicuous because of their mottled wings.¹ The larvæ are phytophagous and feed as leaf and stem miners, gall makers, and in the fruits, husks of seeds and nuts, vegetables, and flower and seed heads of the family COM-

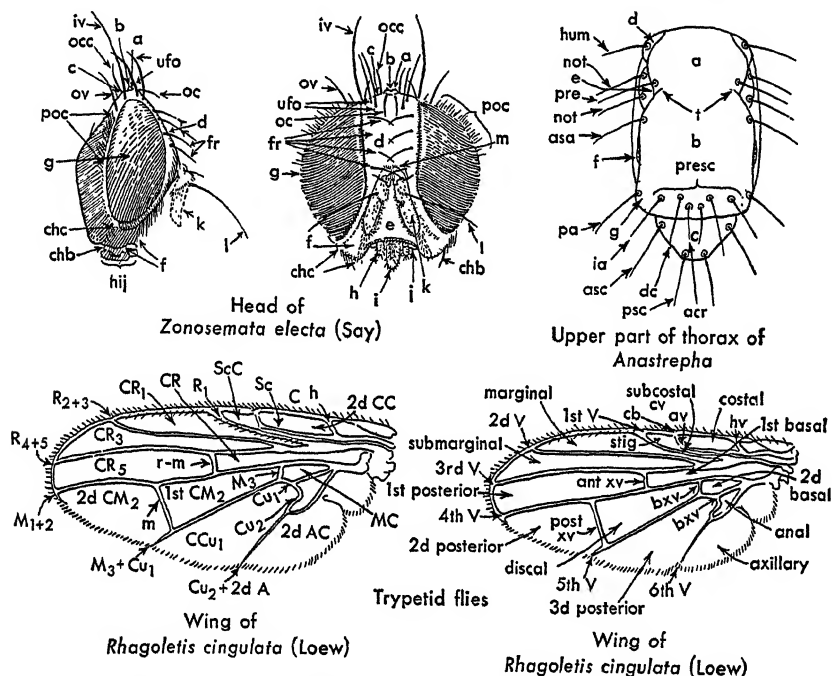


FIG. 293. Characters of the TRYPETIDÆ. Head of *Zonosemata electa* (Say). A, front aspect; B, lateral aspect; a, ocellar triangle; b, ocellus (only one of the three showing); c, vertex; d, front; e, face; f, cheek; g, compound eye; h, palpus; i, tongue or proboscis; j, mouth; k, antenna; l, arista; m, frontal suture; occ, occipital bristle; iv, inner vertical bristle; ov, outer vertical bristle; ufo, upper fronto-orbital bristles; oc, ocular bristle; fr, frontal bristles; poc, postocular cilia; chc, cheek; chb, cheek bristle. Dorsum of thorax of *Anastrepha*. a, prescutum of the mesothorax; b, scutum of same (a and b also known as the thoracic dorsum, notum, or mesonotum); c, scutellum; d, humerus; e, notopleuron; f, wing base; g, postalar callus; t, the suture; hum, humeral bristle; not, notopleural bristles; pre, presutural bristle; asa, anterior supraalar bristle; pa, postalar bristle; dc, dorsocentral bristle; acr, acrostichal bristle; asc, anterior scutellar bristle; psc, posterior scutellar bristle; presc, prescutellar row of bristles. (After Benjamin, U.S. Bur. Ent., 1934.)

POSITÆ. Many species are very serious, destructive pests, and the various fruit and vegetable hosts are excluded from the United States by Federal Quarantines No. 13 and No. 56. No other family of insects is so drastically regulated by law. The family is a relatively large one, consisting of some 900

¹ They may be confused with the members of the related family OTITIDÆ Curran 1934 (ORTALIDÆ Macquart 1835) which are largely phytophagous and may be separated from the latter by the lower frontal orbital bristles, regularly curved subcostal vein, and preapical spurs on the middle tibiae.

species which are chiefly tropical and subtropical with many representatives in the temperate regions.

The most important genera may be arranged according to the food habits of the larvæ as follows:

1. In flower heads of COMPOSITÆ¹ (these include many more than are listed here): *Acanthiophilus* Becker, *Aciura* R.-D., *Ensina* R.-D., *Næta* R.-D., *Ædaspis* Loew (*O. atra* Loew and *O. polita* Loew on goldenrod in North Amer-

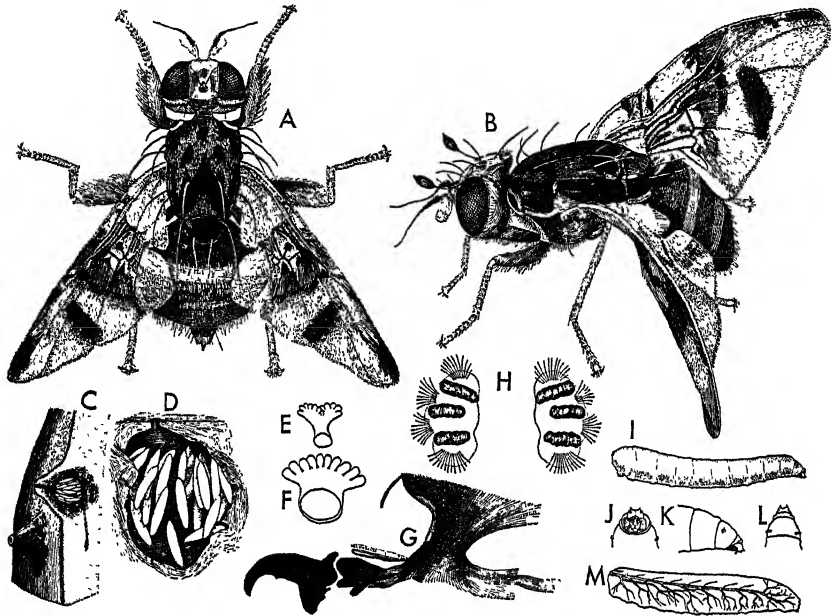


FIG. 294. The Mediterranean fruit fly, *Ceratitis capitata* Wiedemann. A, adult female; B, adult male; C and D, eggs in fruit; E and F, anterior spiracles of larva; G, mouth hooks of larva; H, posterior spiracles of larva; I, mature larva or maggot; J, K, L, anterior end of larva; M, respiratory system of larva. (A and B after Mally, 1904; C and D after Back and Pemberton, 1915; J, K, and L after Silvestri, 1914.)

ica), *Myopites* Brebisson, *Paracantha* Coq., *Tephritis* Latr., and *Trupanea* Schrank.

2. Leaf miners: *Trypeta* Meigen: the celery fly of Europe, *T. heraclei* (Linn.), and the parsnip leaf miner of North America, *T. fratria* Loew and *Philophylla* Rond. infest many umbelliferous plants and are of economic importance.

3. Stem borers and gall makers: *Aciurina* Curran (= *Eurosta* Loew): *A. solidaginis* (Fitch) on goldenrod in North America. *Euribia* Latr.: *E. cardui* (Linn.) common on thistles in Europe. *Eutreta* Loew. *Strauzia*² R.-D.: the

¹ The larvæ of many species of *Urophora* R.-D., *Ensina* R.-D., *Terellia* R.-D., *Urellia* R.-D., and *Tephritis* Latr. infest thistles and centaureas.

² The genus *Strauzia* was established by Robineau-Desvoidy in 1830 and the name amended to *Straussia* by Agassiz in 1846.

sunflower peacock fly, *S. longipennis* (Wied.) of North America. *Tephritis* Latr.

4. Seed pods and husks of seeds and nuts: *Aciura* R.-D.: *A. coryli* Rossi in flowers of mullein in Europe. *Ceratitis* MacLeay: *C. capitata* (Wied.) in husks of coffee berries in the tropics. *Rhagoletis* Loew: *R. suavis* (Loew) and *R. completa* Cresson on wild and cultivated walnuts in North America.

5. In fruits and vegetables: *Anastrepha* Schiner: **Mexican fruit fly**, *A. ludens* (Loew), in citrus and other subtropical and tropical fruits in Mexico, Central America and in extreme southern Texas; **West Indian fruit fly**, *A. fraterculus* (Wied.), a species with similar habits in tropical Central and South America and the West Indies. *Bactrocera* Guérin: a number of tropical species of which the **melon fly**, *B. cucurbitæ* (Coq.), the most important species, seriously injures melons, other cucurbs, and a number of vegetables. *Carpomyia* A. Costa: *C. schineri* (Loew), in the fruits of rose, *Pyracantha*, and *Cratægus* in Europe. *Ceratitis* MacLeay: **The Mediterranean fruit fly**, *C. capitata* Wied., a very general feeder and one of the most serious pests of fruits in the tropical and subtropical regions. It was discovered in a large area in Florida in April, 1929, and was immediately and apparently completely eradicated at a cost of some \$6,000,000. *Chetodacus* Bezzi: **The Queensland fruit fly**, *C. tryoni* Froggatt, a serious pest in northern Australia. *Dacus* Fab.: the **olive fly**, *D. oleæ* Gmelin, a very destructive pest to olives in the Mediterranean region and South Africa. *Epochra* Loew: **The currant and gooseberry fruit fly**, *E. canadensis* Loew, common in many parts of North America. **The asparagus fly**, *Platypara pæcilopectera* (Schränk), a small spotted-winged species 6.5–7.5 mm. long, is a serious pest which mines and destroys the young edible shoots of asparagus in Europe. *Rhagoletis* Loew: **The apple or blueberry maggot**, *R. pomonella* (Walsh), the **cherry fruit flies**, *R. cingulata* (Loew) and *R. fausta* (O.S.), the **wild walnut fly**, *R. suavis* (Loew), of eastern United States, and the **walnut husk fly**, *R. completa* Cresson, of western United States are the most important species in North America, while *R. cerasi* (Linn.) on cherry, *R. alternata* Fallén on *Cratægus*, and *R. meigeni* Loew on *Berberis* are common in Europe. *Toxotrypana* Gerstæcker: the **papaya fruit fly**, *T. curvicauda* (Gerst.), is a serious pest in tropical North America.

Family CHAMÆMYIIDÆ¹ Hendel 1910 (Cham'æ-my-i'i-dæ, from the Greek χαμαι, on the ground, + μυια, a fly; literally, a ground fly). Aphid Flies.

Small, usually dark or grayish, nearly naked, terrestrial flies. Oral vibrissæ absent. Antennæ short; arista basodorsal, bare or pubescent, rarely absent. Fore femora bristled; tibia without preapical bristles. Wings hyaline or pictured. Larvæ living free or in egg masses of the hosts; yellowish or pigmented and cryptic, often gray or green; predacious chiefly on aphids and scale insects

¹ OCHTHIPHILIDÆ Zetterstedt 1890 (from the Greek ὄχθ, bank, water-side, + φιλεῖν, to love).

and therefore beneficial. The three most important genera are *Chamæmyia* Meigen, *Cryptochætum* Rondani,¹ and *Leucopis* Meigen.

The dipterous parasite of the cottony cushion scale, *Cryptochætum iceryæ* (Williston), is one of the natural enemies of *Icerya purchasi* Mask., introduced by F. S. Crawford and Albert Kœbele from Australia into California in 1888-9. The adults are 1.5 mm. long, the head and thorax metallic dark blue, and the abdomen iridescent green. They are rather slow in movement, crawling slowly over the host and inserting one to several minute, oblong, oval, smooth, pearly white eggs preferably in the half-grown scales. It is thought that a single female may lay as many as 200 eggs. The young larvæ are curious, semitransparent, elongated maggots with black mouth hooks, the anterior half of the body bare, the posterior half ciliated, and with two long tail-like processes often twice the

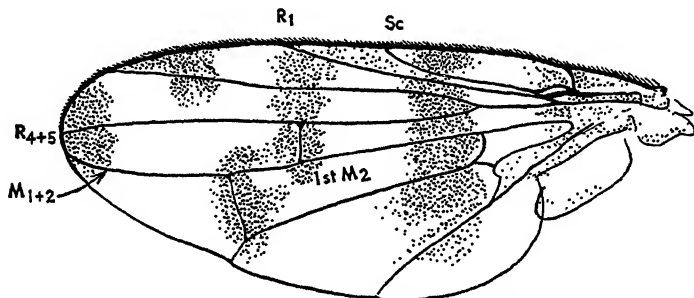


FIG. 295. Wing of the otitid fly, *Anacamptis latiuscula* Loew.

length of the body. The full-grown larvæ are quite different. The body becomes pear-shaped with two horn-like tracheæ, and the tail-like processes extended to four or five times the length of the body. The color becomes reddish from the contents of the alimentary canal. The larvæ live freely within the body cavity of the host, feeding on the body fluids and apparently not seriously inconveniencing it; when the larvæ reach maturity, however, the host is eventually killed. Several larvæ may occur in a single scale insect. Pupation occurs within the dead body of the host. The puparia are yellow or reddish-brown, oval, 2 mm. long, with two horn-like projections. There are five or six generations a year.

Leucopis bella Loew and *L. bellula* Williston are small gray flies, the larvæ of which feed on the eggs and young of mealybugs in North America. *L. griseola* (Fallén), 1.25 mm. long, and *L. nigricornis* Egger occur in Europe and North America. The larvæ are free living on the foliage of plants and feed on aphids. *L. simplex* Loew, widely distributed in the United States, feeds upon phylloxerids and adelgids, and *L. obscura* Haliday has similar habits in Europe.

Species of *Chamæmyia* Meigen (*Ochthiphila* Fallén) including *C. polystigma* (Meigen) feed on grass-infesting mealybugs, and *C. aridella* (Fallén) feeds on various coccids in Europe.

¹ Placed in a separate family, CRYPTOCHÆTIDÆ, by some authors.

Family **DROSOPHILIDÆ** Loew 1862 (Dro'so-phil'i-dæ, from the Greek *δρόσος*, dew, + *φιλεῖν*, to love). German, Taufliegen. Vinegar Flies.

Small, mostly pale-yellowish or tawny flies, many of which are attracted to decaying and fermenting vegetable materials including fruits. The members constitute a small family of widely distributed species. The most important

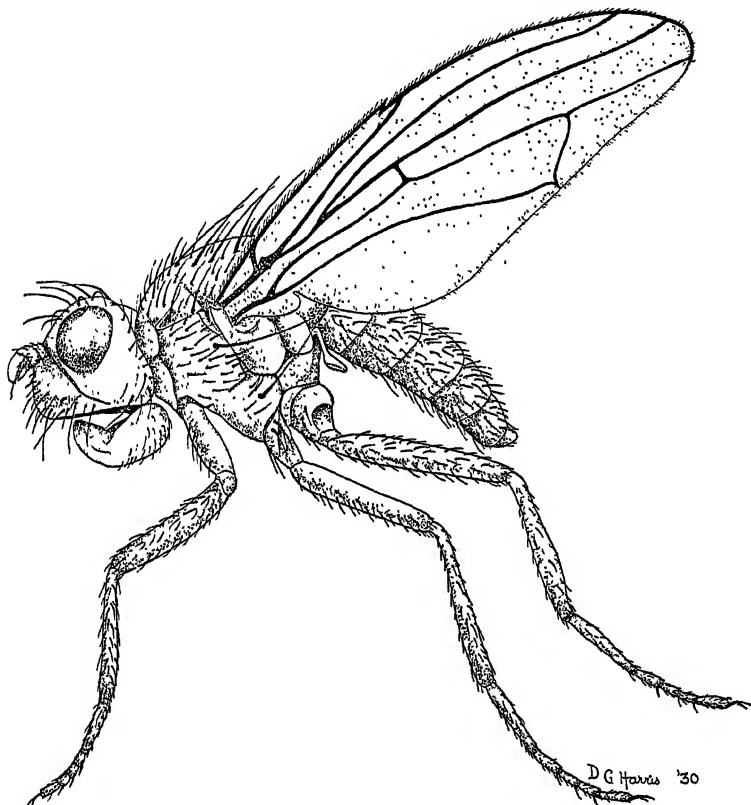


FIG. 296. The koo-isabe fly, *Ephydra hians* Say, a species that breeds in saline lakes in California and the pupæ of which are used for food by the aborigines. (From *A History of Entomology*.)

species in the family and one of the most famous and best known insects is the vinegar or pomace fly, *Drosophila melanogaster* Meigen, yellowish, 3 mm. long, which has been used so extensively by geneticists in the laboratory studies of inheritance, especially in reference to the gene theory. The larvæ are easily and quickly reared on fermenting bananas and other fruits which makes this species particularly well adapted for life history studies in entomology. This fly was first suggested as an experimental laboratory animal by C. W. Woodworth, University of California in 1900-01. (C. B. Davenport, *Science* **93**:

305-6, 1941.) It is now cosmopolitan in distribution. The European species of this genus are divided into seven subgenera. The eggs are very minute, oblong, with reticulated surface and two appendages as long as the egg. The maggots are whitish or dusky and 7 mm. long. The pupæ have two horn-like respiratory tubes.

Family AGROMYZIDÆ¹ Bigelow 1852 (Ag'ro-myz'i-dæ, from the Greek *ἀγρός*, a field, farm, + *μύα*, a fly). German, Minierfliegen. Leaf Miners.

Minute to small flies, varying from 1.5-4.0 mm. long; usually blackish or yellowish in color; with postocellar bristles and oral vibrissæ; arista dorsal and basal and bare or pubescent; femora bristled; wings hyaline or pictured. The larvæ are apparently all phytophagous, and many of them produce characteristic serpentine or blotch mines, particularly on the leaves of broad-leaved evergreen and deciduous shrubs and trees.

This family is a comparatively large one, is widely distributed, and contains many species of economic importance. The most important genera are *Agromyza* Fallén (about 100 described species are known which attack a large list of wild and cultivated plants), *Cerodonta* Rondani, *Dizygomyza* Hendel, *Liriomyza* Mik, *Napomyza* Haliday, and *Phytomyza* Fallén (a large genus with about 100 species listed on known host plants). The genera are not all clearly agreed upon by the various workers in this family, so it is impossible to place all of the species definitely.

Family CHLOROPIDÆ² Rondani 1856 (Chlo-rop'i-dæ, from the Greek *χλωρός*, greenish, + *ὤψ*, eye; referring to the green eyes of the adults). German, Halmfliegen. Frit Flies, Grass Flies, Stem Flies.

Minute to very small, mostly pale, naked or slightly hairy, active flies. Head somewhat angular; oral vibrissæ reduced or absent; vertical triangle unusually large. Antennæ prominent and porrect; arista dorsal, basal (rarely terminal), bare, pubescent, or plumose. Wings with subcosta reduced; second discal and basal cells united; anal cell wanting; fourth vein curved. Larvæ short, cylindrical; mouth hooks prominent; antennæ two-segmented; fleshy larvapods present. The maggots bore into the stems or mine the leaves of grasses, and cultivated members of the GRAMINEÆ and the adults may be taken in great numbers by sweeping these plants with an insect net. They often also occur in large numbers on many kinds of shrubs and trees. While the adults average about 2.5 mm. in length, *Neuropachys brachyptera* Thalhammer, a brachypter-

¹ According to Frost (1923), there are at least 287 genera and 589 species in 12 families of flies that are leaf and stem miners. They have been reared from 66 different families of plants. Other important families of flies, not discussed in this work, that contain leaf- and stem-mining species are: CARNIDÆ, LONCHÆIDÆ, PHYLLOMYZIDÆ, ODINIIDÆ, OPOMYZIDÆ, and PALLOPTERIDÆ.

Certain species have also been placed in the family PHYTOMYZIDÆ Fallén 1810 which is generally considered to be a synonym of several of the above.

² OSCINIDÆ Fallén 1820 (from the Latin *oscen*, *oscinis*, a singing bird) is a synonym of this family name.

ous species of Europe, is only 0.75 mm. long and *Lipara luceus* Meigen, also of Europe, is 6–8 mm.

The most important and widely distributed genera are: *Chloropisca* Loew; *C. glabra* (Meigen) on grasses throughout the Holarctic region; *C. circumdata* (Meigen) and *C. oryzae* Matsumura on rice in Japan; *Chlorops* Meigen, a very large and cosmopolitan genus, *C. pumilionis* Bjerk on grasses and cereals in the Mediterranean Basin; *Hippelates* Loew, the larvæ of which are largely saprophagous and coprophagous, and the adults of which often appear in

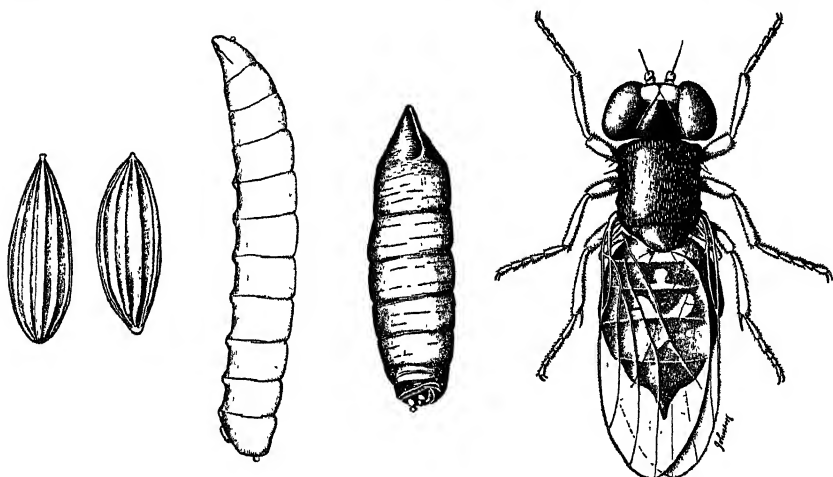


FIG. 297. The Coachella eye gnat, *Hippelates pusio* Loew. Eggs, larva, pupa, and adult. (Redrawn from Hall, 1932.)

great numbers in the spring and fall of the year. The eye gnat, *H. pusio* Loew, is a tormenting pest of domestic animals and man in parts of southern California and may transmit the so-called pink-eye disease of humans. *H. flavipes* Loew and *H. plebejus* Loew have similar habits in tropical America; *H. jacobsi* Tonnoir is European but apparently not important. *Siphunculina funicola* de Meij. is the common eye fly of India. It spreads Naga sore and conjunctivitis or sore eye. *Meromyza* Meigen; *M. pratorum* Meigen, *M. saltatrix* (Linn.), and *M. variegata* Meigen are all small yellow species which are serious pests of cereals in Europe while *M. americana* Fitch is the most important cereal-infesting species in North America. *Oscinosoma* Lioy (*Oscinis* Latr.) contains the most important member of the entire family and one of the most injurious pests of growing cereals, the frit fly, *O. frit* (Linn.), 1.0–1.5 mm. long, a widely distributed Holarctic species which attacks a large number of cereals and grasses belonging to the family GRAMINEÆ. There are literally hundreds of species belonging to this family which are of economic importance as phytophagous insects.

The larvæ of *Pseudogaurax signata* (Loew) (*Gaurax araneæ* Coq.) are pre-

dacious on the eggs of the black widow spider, *Latrodectus mactans* (Fab.), in various parts of North America.

j. Series CALYPTRATÆ Macquart 1883

(1) Superfamily MUSCOIDEA Comstock 1924

Family ANTHOMYIIDÆ¹ Loew 1862 (An'tho-my-i'i-dæ, from the Greek *ἄνθος*, a blossom, flower, + *μύια*, a fly; literally, flower flies). German, Blumenfliegen. Root Maggots, Anthomyiid Flies.

Small to medium-sized, slender, bristly, active flies which are usually black, gray, or dull yellow in color. Head large and free. Eyes large, separated or holoptic in some males. Antennæ with bare, pubescent, or plumose aristæ. Proboscis fleshy. Wings with first posterior cell wide open; M_1 vein only slightly turned up apically. Squamæ large. Abdomen usually bristly, four- to five-segmented, genitalia of males well developed in some individuals. Larvæ variable but in most cases of the muscoid type; cylindrical and truncate posteriorly; with two mandibular hooks; the spiracular slits short and disposed radially; two tubercles above the anal area; and the spiracular area encircled by

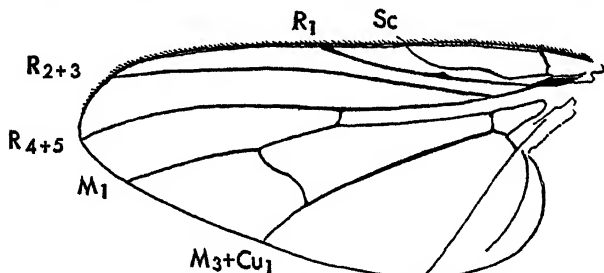


FIG. 298. Wing of the anthomyiid fly, *Spilogaster* sp.

processes. In *Fannia* the body is flattened, narrowest anteriorly, and each segment with dorsal, lateral, and ventral fleshy and spinose processes. The larvæ are mostly saprophagous and feed on dung and decayed vegetable and animal matter. A certain number of important genera and species are phytophagous and very injurious to cultivated plants whereas other genera are carnivorous and annoying to or cause accidental myiasis in the alimentary tract of man and other animals.

There are a considerable number of important phytophagous species which are widely distributed in the north temperate region. They are for the most part small, black and gray, hairy species which usually lay the small elongated, sculptured eggs singly or side by side in series on the hosts and rarely in the soil. The onion maggot, *Hylemya*² *antiqua* (Meigen) [*Phorbia ceparum* (Meig.)],

¹ The exact status of this and related families in the superfamily MUSCOIDEA is quite uncertain, and no two modern students of the DIPTERA are in agreement as to classification.

² The name *Hylemya* Robineau-Desvoidy 1830 was amended to *Hylemyia* by Macquart in 1835. The former has precedence.

of Europe and North America attacks the bulbs of onions and related plants. The wheat bulb fly, *H. coarctata* (Fallén), of Europe and Northern Asia feeds on the roots and stems of wheat. The eggs are laid indiscriminately in the soil. The western wheat stem maggot, *H. cerealis* (Gillette), attacks wheat in western North America. The seed corn maggot, *H. cilicrura* (Rondani) (= *fusciceps* Zett.) of Europe and North America is an injurious pest of planted seeds and young plants and the larvæ also feed in decayed vegetation and dung. The cabbage maggot, *Chortophila brassicæ* (Bouché), is a very serious pest of many cruciferous plants, the larvæ feeding in the stems of the hosts. It is widely distributed in Europe and North America. The raspberry cane borer, *Phorbia rubivora* Coq. of North America, kills the growing shoots of berries and roses. The beet or spinach leaf miner, *Pegomya*¹ *hyoscyami* (Panzer) (= *vicina* Lintner), of Europe and North America differs from the other species enumerated above in that the larvæ are leaf miners making large blotch mines in the leaves of beets, spinach, atriplex, lamb's-quarters, and other related plants. The root maggot, *Paregle radicum* (Linn.), of Europe is a common serious pest of cruciferous plants.

Among the common scavengers are members of the genus *Fucellia* Robineau-Desvoidy, including *F. fucorum* Fallén of Europe and North America and *F. rufitibia* Stein of the Pacific coast of North America, which feed upon kelp and brown seaweeds along the ocean beaches. *Orcmisia costata* (Meigen) (*Orchisia*) is distributed throughout the Old World. *Ophyra nigra* Wied. is a shining black species, similar to the housefly that is common in the Oriental, Pacific, and Australian regions.

Members of the genera *Hydrotæa* Robineau-Desvoidy, *Melanochelia* Rondani, *Mydæa* R.-D., *Passeromyia* Villeneuve, and *Phaonia* R.-D. are recorded as being either carnivorous on nesting birds or annoying to domestic animals. The larvæ of *Mydæa anomala* Jænn. cause subcutaneous myiasis of birds in South America, and the adults of *Hydrotæa irritans* (Fallén) annoy cattle and horses in Europe. The most important members in this rôle belong to the genus *Fannia* R.-D. which commonly breed in dung and decayed animal and vegetable matter. The lesser housefly, *F. canicularis* (Linn.), 3-5 mm. long, the latrine fly, *F. scalaris* (Fab.), *F. manicata* (Meigen), and *F. incisurata* (Zetterstedt) are Old World species now widely distributed in North America and other parts of the world. They breed under very unsanitary conditions and occasionally the larvæ accidentally cause internal myiasis in man.

Family GLOSSINIDÆ Malloch 1929 (Glos-si'ni-dæ, from the Greek γλῶσσα, tongue; referring to the long proboscis). Tsetse Flies.

Medium-sized, 5-10 mm., brownish flies slightly larger than the common housefly; mostly bare with few short bristles and a tuft of long hairs on the face. Proboscis needle-like, with apical teeth, porrect, ensheathed in long slender palpi. Antennæ three-segmented, first very small, second, short, hairy; arista

¹ *Pegomya* Robineau-Desvoidy 1830 was amended to *Pegomyia* by Macquart in 1835. The former stands.

with long, feathered hairs along the upper surface. Prosternum membranous. Metasternum projected forwards between the middle coxæ. Wings overlapped when folded and extending well beyond tip of abdomen. Abdominal spiracles in the membrane between the tergites and pleurites. Eggs develop singly, hatch, and the larvæ are matured within the uterus where they are nourished by special glands. Fully developed larvæ are yellowish-white excepting the black posterior extremity. They are deposited by the female on the ground in a shady place usually in close proximity to water and immediately enter the soil and pupate. The pupæ are oval, with two nearly globular anal protuberances. The flies emerge in about 30 days. Both sexes suck blood and are essential intermediate hosts of a number of trypanosomes that cause very serious and usually fatal results to man and to domestic and wild mammals.

The family is a small one and comprises a single genus, *Glossina* Wiedemann 1830, 21 species, two subspecies, and seven or eight varieties. These all occur in tropical and subtropical Africa, and one species was once reported in Arabia. The species are arranged in three groups (Neveu-Lemaire 1938), each group associated with an important species listed first as follows:

Glossina fusca (Walker 1849), *fusca* group, 10 species and two varieties. They play a minor rôle in the transmission of African sleeping sickness, a very fatal disease to man caused by *Trypanosoma gambiense* Dutton.

Glossina palpalis (Robineau-Desvoidy 1830), *palpalis* group, five species, two subspecies, and three or four varieties. The members of this very important group transmit to man Gambian sleeping sickness caused by *Trypanosoma gambiense* Dutton; *T. uniforme* Bruce of sheep and goats; and Souma, a disease of cattle and horses caused by *T. vivax* Ziemann.

Glossina morsitans Westwood 1850, *morsitans* group, six species and two varieties. The members transmit the trypanosomes *Trypanosoma rhodesiense* Stephens and Fantham, causing Rhodesian sleeping sickness; *T. brucei* Plimmer and Bradford causing Nagana, a disease fatal to cattle and horses; *T. capræ* Kleine, also causing Souma, a disease of ruminants; and *T. suis* Ochmann, infecting swine.

Family MUSCIDÆ (Fallén 1810) Leach 1815, 1819 (Mus'ci-dæ, from the Greek *μῦς*, fly, and the Latin *musca*, fly). German, Echte Fliegen. Houseflies.

Small to medium-sized flies, 3–8 mm., short; nearly bare or bristly and usually with short macrochætæ. Head large, free. Eyes large; usually separated, rarely holoptic in males. Proboscis fleshy; wholly or only partly retractile; labella well developed for lapping food and for exuding saliva or vomit drops. Antennæ three-segmented; apical segment large; arista basal and plumose to the tip, but the lateral hairs are not feathered. Hypopleural bristles usually absent. Wings large and strong; apical cell narrow; tip of the vein M_1 with sharp or weak upward curve and ending above or below the wing apex. Squamæ well developed. Halteres small. Abdomen hairy; short and with constricted base; basal area without macrochætæ. Spiracles on tergites II to V. Larvæ pale; muscoid type; cylindrical; pointed anteriorly and truncate poste-

riorly; distinctly segmented; ventral pseudopods present; four or more tubercles above the spiracular area; metapneustic; the pair of posterior spiracles hemispherical and each with three radially arranged, slit-like openings; anterior spiracles each with six to eight processes; 6–10 mm. long. Pupæ enclosed

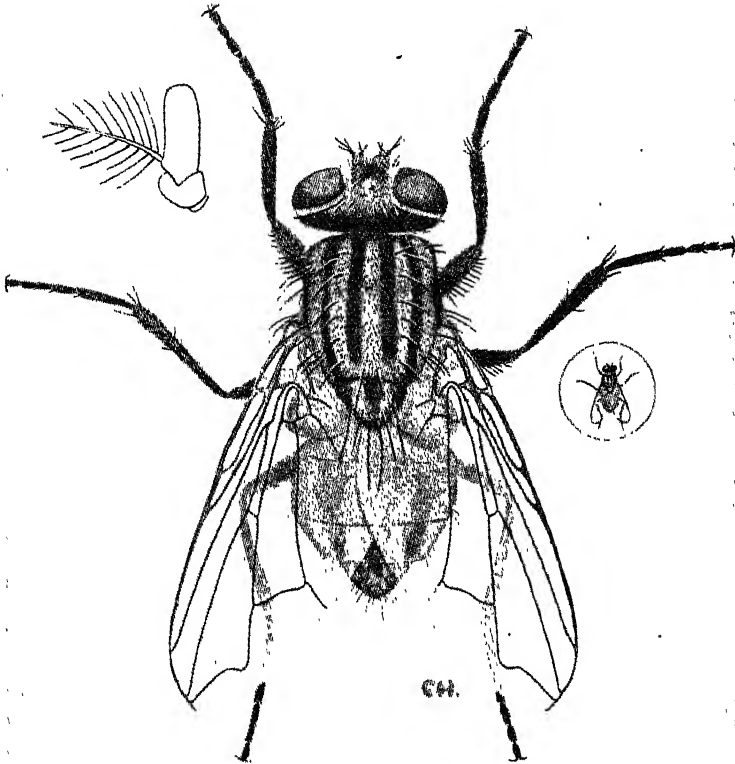


FIG. 299. The common housefly, *Musca domestica* Linn., a species long associated with the human race. (After Gibson and Twinn, 1931.)

in last larval skin (puparium); yellowish or reddish-brown, oval; 3–6 mm. long; segmentation visible.

As now constituted, this is a small family of some 25 genera and about 100 species that make up a group of closely related saprophagous species. As larvæ, they are of little or no consequence, but the adults, which often appear in great multitudes, are a source of much annoyance to man. A number of species trans-

mit serious diseases to man and domesticated animals, and the larvæ cause intestinal myiasis. Among the most important north temperate genera are *Musca* Linn. and *Muscina* Robineau-Desvoidy (cosmopolitan), *Graphomyia*¹ R.-D., *Mesembrina* Meigen, *Myospila* Rondani, *Morellia* R.-D., *Pyrellia* R.-D., and *Pseudopyrellia* Girschner.

By far the most important species is the cosmopolitan housefly, *Musca domestica* Linn. 1758, which was no doubt intimately associated with man even before he had domesticated mammals. Only a few years ago the adults occurred in practically every household throughout the civilized world, but since the advent of the automobile and elimination of horse and cow stables in towns and cities there are large areas where these pestiferous insects either do not occur at all or are very rare and only occasional visitors.

The adults are various shades of black, gray, and yellowish, usually with four dark longitudinal vittæ on the pronotum, and only 4.0–7.5 mm. long. One of the chief distinctions is that the distance between the eyes almost equals the width of each eye. They are slow and sluggish in cold weather and rest at night on the ceilings, walls, and fixtures in the houses, where they also spend the winter, oblivious to the conditions out of doors. During the spring, summer, and fall they are very active and are into everything that may have possibilities of food value and become most pestiferous. Of course they propagate outside, laying the small slender white eggs in great numbers, from 500 to 2,000. They are especially prone to lay eggs in horse manure, but they readily breed in any kind of dung, garbage, and decomposing vegetable and animal matter. The eggs, white, slender, and 0.8–1.0 mm. long, hatch within a few days. The white larvæ feed upon and grow rapidly in the manure, where they may occur in countless millions on farms and dairies where horses, cattle, poultry, and other animals are kept.

The larvæ are 7–10 mm. long; pointed anteriorly and truncate and rounded posteriorly; pale yellow or whitish; the anterior pair of spiracles with six or seven finger-like openings; posterior spiracular areas D-shaped, the three slit-like openings pointed inwardly. They may mature in as few as 4 or 5 days and, after spending less than a week as pupæ, issue as adult flies. With such a short life history, consuming but 10 to 14 days, there may be from 10 to 20 generations per year depending upon the latitude and climatic factors.

While only a few years ago flies were scarcely noticed and were allowed free leave to walk over the food and dishes on private and public tables alike, at the present time health officials and the general public have been so thoroughly aroused to the menace of these disease-bearing insects that they are no longer tolerated inside or out. Aside from their presence and annoyance, houseflies carry and frequently transmit a number of serious diseases including typhoid fever, infantile diarrhœa, bacillary and amœbic dysentery, cholera, trachoma, and tuberculosis. According to Patton (1931) a single housefly may carry and

¹ Students are reminded that the common Greek form is *μῦα* (Latin, *musca*), a fly. The Attic Greek was *μῦα*. Hence the transliterated forms *myia* and *mya* each have a basis in etymology.

contain from 800,000 to 500,000,000 aerobic bacteria, but these may represent many species which do not cause diseases in man. They may also distribute the eggs and young larvæ of parasitic worms and rarely produce intestinal myiasis in man as well as be an intermediate host of certain poultry tapeworms. The causal agencies of these various diseases are carried on the feet or may be actually disseminated by regurgitation or vomit on human food and elsewhere where they may be acquired by children and adults. Fly specks, which once covered walls, ceilings, and hangings, are combinations of excrement and vomit. Modern health regulations, combined with a better general knowledge of flies and their relations to filth and diseases, and general progress have gone far in either eliminating or greatly restricting the housefly in many parts of the civilized world, while in less progressive countries and especially in the subtropical and tropical regions houseflies remain for the most part unmolested.

In addition to the housefly, there are about 30 other species in the genus *Musca*. Of these the most important are: *M. autumnalis* DeGeer (*M. corvina* Fab.) of Europe and southern Asia; *M. sorbens* Wied., *M. tempestiva* Fallén, *M. vicina* Macquart, and *M. vitripennis* Meigen from the Mediterranean Basin eastward throughout southern Asia. *M. vicina* Macq. is the common housefly of the Orient and the commonest species in Hawaii. *M. lusoria* Wied. and *M. vetustissima* Walker are widely distributed African species, the latter being also the commonest Australian housefly. *M. nebulosa* Wied. is an Old World tropical and subtropical species.

The squash root maggot, *Muscina assimilis* (Fallén), of Europe and North America and the cosmopolitan *M. stabulans* (Fallén) are largely saprophagous, but the larvæ may also feed on and injure the roots of many vegetable and field crops. The latter is thought also to disseminate intestinal myiasis to man (Riley and Johannsen, 1932).

Family STOMOXYIDÆ Meigen 1824 (Sto-mox'i-dæ, from the Greek *στόμα*, mouth, + *ὄξύς*, sharp, keen; from the sharp proboscis). Stomoxid Flies, Stable Flies, Horn Flies.

Small flies similar to the common housefly in general appearances. Proboscis long, rigid, sharp, with small labella; for piercing and sucking blood. Arista bare, pubescent or pectinate, with long hairs only on the dorsal surface. The lower squama (calypter) rounded posteriorly; inner margin distant from the scutellum. Larvæ typically muscoid. They are saprophagous and are to be found especially in dark moist places wherever food is available. The adults of some genera are very annoying to man and domestic animals because of their blood-sucking propensities.

The best known species is the stable fly or biting housefly, *Stomoxys calcitrans* (Linn.), 6.5 mm. long, gray, which is very similar to and often mistaken for the housefly. It is distinguished by the more pronounced and interrupted dorsal vittæ of the thorax, the shorter, checkered abdomen, the prominent slender proboscis, short palpi, and the angular poise of the wings when at rest. The adults are abundant out of doors but readily invade buildings and often prove a

great nuisance to the inmates. They are bloodsuckers and serious tormentors of man and domestic animals which they bite with avidity. The larvæ breed normally in decaying grass or straw and often occur in enormous numbers in piles of lawn clippings which may become sources of serious invasions of the flies. Some breeding occurs in manure and waste vegetable materials. The species is distributed throughout Europe and North America and, with the housefly, occurs wherever there are habitations.

The horn fly, *Hæmatobia stimulan* (Meigen) (= *irritans* Fab.), 4.0–5.5 mm. long, is more slender than the housefly and about the same general color. The palpi are nearly as long as the proboscis. The fly gets its common name from the habit of resting in great numbers at the bases of the horns of cattle, but it gathers on the rump, neck, and sides as well. The adults are vicious biters of and greatly torment wild and domestic animals, and remain on them day and night and cause loss of vitality and reduce the efficiency of milk cows. While they persistently annoy man they rarely actually bite him. The maggots breed in manure. The fly is common in Europe and was early introduced into America although not definitely known until 1887. It now occurs practically wherever cattle are raised.

The closely related European *Lyperosia irritans* (Linn.) (= *serrata* R.-D.) is similar to the preceding species in size, color, and habits. It also occurs in the West Indies and United States. The blood-sucking buffalo fly of Malaysia is *L. exigua* (de Meijere). It commonly attacks water buffalo, cattle, and horses and causes considerable losses to the cattle industry in Australia and may carry infectious diseases. The eggs are laid singly in dung in which the maggots live.

Family GASTEROPHILIDÆ Bezzi and Stein 1907 (Gas'ter-o-phi'li-dæ, from the Greek γαστήρ, γαστρός, the stomach or belly, + φίλος, loving; because the larvæ of some species live in the stomach of the host). German, Magenbremsen. Horse Botflies, Breeze Flies.

Medium-sized, 9–18 mm. long, stout, pollinose flies without bristles. Eyes large. Ocelli present. Antennæ depressed in facial grooves; arista bare. Proboscis short; mouth parts poorly developed; palpi short, expanded, larger than the proboscis. Thorax pilose. Scutellum large. Postscutellum absent. Wings large; hyaline or with dusky spots; apical cross vein absent. Squamæ small. Abdomen oval in the males and pointed in the females; ovipositor large and protrusile. Eggs somewhat triangular or stalked; glued to hairs with point downwards; in series of from two to many. Larvæ called bots; robust; cylindrical, pointed anteriorly; with two pairs of mouth hooks; most segments encircled by one or more rows of short spines; 12–18 mm. long. They are endoparasites of the alimentary tract, chiefly of asses, horses, mules, and related animals, and rarely or accidentally occur in dogs, rabbits, and man. Some authors place all the members in the single genus *Gasterophilus* Leach (*Gastrophilus*), but others group them also in the genera *Gyrostigma* Brauer, *Rodhainomyia* Bequaert, *Ruttenia* Rodhain, and *Cobboldia* Brauer. There are about 20 species

which are mostly indigenous to the Old World but some of which have been widely distributed by commerce.

The horse bot- or nit fly, *Gasterophilus intestinalis* DeGeer [= *equi* (Clark)], is the common stomach bot of horses, asses, and mules. The adult may attain a length of 18 mm. and is brownish and somewhat resembles a honeybee but has a whitish face, dusky wing spots, and often three rows of dusky spots on the dorsum of the abdomen. These flies are slow of flight and are to be found about horses upon which they attach the minute, elongated, pale-yellow nits or eggs to the hairs of the forelegs, shoulders, chest, belly, and other parts of the body. To induce hatching, which occurs in from 10 to 14 days, they are supposed to require friction and moisture furnished by licking them off the hairs. The small hairy first-stage larvæ are transferred by the tongue and lips to the mouth, through the tissues of which the larvæ penetrate and migrate to the stomach. They subsequently attach themselves by means of the strong mouth hooks to the walls of the stomach, from which nourishment is procured. In severe cases the walls may be entirely lined with crowding bots which, when full grown, are tough, oval, distinctly segmented, spiny maggots 15-18 mm. long. They remain in the stomach from summer through the winter and reach maturity in the spring when they loose their hold, pass to the ground, and pupate in the soil, emerging as flies in from 3 to 5 weeks. The species is now nearly cosmopolitan in distribution.

The nose botfly, *Gasterophilus hæmorrhoidalis* (Linn.), oviposits on the lips, and the larvæ are first attached in the stomach and subsequently transfer to the rectum of horses. It is now widely distributed, especially in Europe and North America. The throat botfly, *G. nasalis* (Linn.) [= *veterinus* (Clark)], oviposits under the head and in the region of the throat, and the larvæ are attached to the pharynx, stomach, and duodenum of horses and mules. The larvæ of *G. pecorum* (Fab.), a widely distributed Old World species, lay eggs on the food of the host and on nearby objects and infest the stomach and duodenum of horses, asses, mules, and rarely rabbits and even man; *G. conjugens* Enderlein, *G. meruensis* (Sjöstedt), and *G. pavesii* (Corti) are attached to the stomach of rhinoceroses in Africa; and *G. sumatrensis* Brauer to the stomach of rhinoceroses in Sumatra. Two common species inhabit the stomach of elephants: *Cobboldia elephantis* (Steel) infests the Indian elephant of Asia; *Platycobboldia loxodontis* Rodhain infests the feet, and *Rhodainomyia chrysidi-formis* (Rodhain and Bequaert) the stomach of the elephant of Africa.

(3) Superfamily TACHINOIDEA Enderlein 1936

Family HYPODERMATIDÆ (Rondani 1856) Townsend 1916 (Hy'po-dermat'i-dæ, from the Greek ὑπὸ, under, + δερμα, skin; from the habits of the larvæ living under the skin). German, Dasselfliegen. Warble Flies, Heel Flies, Bomb Flies.

Large, robust, hairy or pilose, bee-like flies, similar to the botflies. Facial grooves broadly separated. Arista bare. Proboscis present or absent. Apical

part of the scutellum bare or hairy. Palpi small or absent. Wings large and permitting rapid flight. Apical cell open.

A description of the very common Old World but now cosmopolitan **cattle warble or heel fly**, *Hypoderma lineata* (De Villiers), will serve as an example of the family. The adults are large, robust, black and white hairy species, 13 mm. long, with a tuft of whitish hairs on each side of the prothorax, the disk of the thorax almost bare but with four longitudinal vittæ and the terminal hairs of the abdomen orange red. The small oval or elongated white eggs 1 mm. long are attached, usually in series, to the hairs, about the feet of the forelegs, sides, belly, and base of the tail, and upon hatching first migrate anteriorly to the œsophageal region and afterwards travel through the connective tissues until they reach the back where they remain embedded just under the hide and complete development, causing lumps or warbles. A small hole through the skin is made for respiration through which waste materials are discharged and the full grown maggot eventually escapes. Pupation occurs in the soil. Besides the annoyance, loss of flesh, and great reduction in the milk supply of dairy cows, the holes in the hides greatly reduce their value for leather, and the annual losses, the world over, to this product are very great.

A closely related species, *H. bovis* (DeGeer), attacking cattle in Europe and other parts of the world, including North America, is also a very severe pest. *H. diana* Brauer infests deer in Europe. *Portschinskia neugebaueri* (Portsch.) is thought to infest the alpine ibex, *Capra ibex* Linn., in the Alps. *Æstrosomyia satyrus* Brauer attacks the field mouse and *Ædemagena tarandi* (Linn.), the reindeer. The larvæ of some of these have been known to cause accidental intestinal myiasis in man.

Family CESTRIDÆ (Leach 1815, 1817) (Es'tri-dæ, from the Greek *οἶστρος*, a gadfly). German, Nasenbremsen. Botflies, Gadflies, Nose Flies.

Large, robust, densely pilose or hairy, bee-like rare flies with large head. Eyes naked, small. Ocelli present. Antennæ depressed in sunken facial furrows; arista bare. Mouth parts atrophied; thorax enlarged; hypopleural hairs long and dense. Wings and squamæ large. The females oviposit or larviposit. The larvæ are large, segmented, and spiny; elliptical; mouth hooks present; anterior spiracles small, posterior spiracular disks nearly circular, concealed in a pit and surrounded by a circlet of spines. They are parasitic in the nasal cavities of wild and domestic animals such as sheep, goats, deer, reindeer, and camels, and rarely also in man. The important genera are *Cephalopina* Strand (= *Cephalopsis* Towns.), *Cephenemyia* Latr., *Æstrus* Linn., and *Rhinæstrus* Brauer.

The most injurious species is the **sheep botfly or sheep gadfly**, *Æstrus ovis* Linn., 12 mm. long, large, hairy, dull-yellow, active fly which appears in the hot sunshine of late spring and summer. The females strike or larviposit in the nostrils of sheep or goats which appear to sense the danger and run with frenzy when the flies attempt to strike. The maggots inhabit the nostrils, frontal sinuses, and maxillary sinuses and do not mature until the following spring or

about 10 months later. They are white or yellowish, 20–30 mm. long and 7 mm. in diameter. Their presence causes extreme annoyance, pain, and death. When mature they drop to the ground, pupate in the soil, and the adults emerge in 6 to 8 weeks. The species is indigenous to the Old World and has been widely distributed with the hosts to many parts of the New World. In North America it has been reared from sheep, goats, and wild deer.

The North African camel cestrid, *Cephalopina titillator* (Clark) (= *maculata* Wied.), has similar habits. It larviposits in the nostrils of camels and the larvæ lodge in the nasopharynx, causing great pain and hindering breathing. Here they remain from 10 to 11 months. This species occurs in eastern Europe and in Asia (Tzaprun, 1935). *Rhinæstrus purpureus* (Brauer) is an obligatory para-

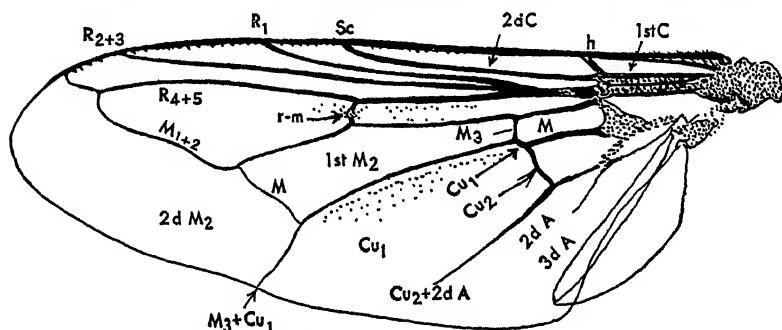


FIG. 300. Wing of the sheep botfly, *Cestrus ovis* Linn.

site in the nasal chambers and sinuses of horses and mules and accidentally in man. It occurs in Europe, northern Africa, Siberia, and Asia Minor. In Europe there are four species of *Cephenemyia* that larviposit in the nostrils and the larvæ of which lodge in the throat of the members of the deer family: *C. rufibarbis* Meigen on red deer, *C. stimulator* Clark on roe deer, *C. trompe* (Linn.) on reindeer, and *C. ulrichii* Brauer on elk. In North America *C. pratti* Hunter attacks deer.

The larvæ of *Pharyngolobus africanus* Brauer inhabits the pharynx of the African elephant and those of *Tracheomyia macropi* Froggatt the tracheæ of kangaroos in Australia.

Many extravagant claims have appeared in print regarding the rapid flight of these deer bots: from 200 to 700 miles per hour. It is most probable that they average 30 or 40 miles an hour but as a matter of fact they can scarcely exceed the speed of 50 miles per hour (*Illustrated London News*, Jan. 1, 1938; *Science* 87: 233–234, 1938).

Family CUTEREBRIDÆ Brauer 1889 (Cu'ter-eb'ri-dæ, from the Latin *cutis*, skin, + *terebrā*, a borer; referring to the skin-boring maggots). Robust Botflies.

Large hairy flies which are rarely taken although the larvæ are not uncommon. Head with receptacle for receiving the proboscis. Proboscis reduced; oral

opening large; palpi very small. Eyes large; separated in both sexes. Arista naked or plumose. Scutellum elongated. Wings and squamæ large. Vein M sharply bent. Macrochætæ only slightly developed. Larvæ robust, strongly segmented maggots, remarkably large in some species; living under the skin of living animals. Members of the genus *Cuterebra* Clark cause large tumor-like swellings.

The most important species is the so-called **human botfly**, *Dermatobia hominis* (Linn.) (= *cyaniventris* Macquart), of North and South America which has a remarkable life history. The females oviposit on mosquitoes, other flies, and even ticks and are thus transported to man. Upon hatching and because of the warmth of the body of the host the young larvæ leave the carrier when the latter visits man and bore through the skin and into the muscular tissues, where they become more or less localized. The full-grown larva is peculiar in being somewhat globular, spiny, and with the posterior half attenuated and tail-like. From 45 to 55 days are required for development and much pain is caused (Curran, 1934; Lane, 1936). For the Americas, Curran lists the genera *Cuterebra* Clark, infesting rabbits, other rodents, and large domestic animals; *Dermatobia* Brauer; *Pseudogametes* Bischoff; and *Rogenhoferia* Brauer. The family is a very small one with probably less than 50 described species which appear to be restricted to the New World.

Family CALLIPHORIDÆ¹ Brauer 1889 (Cal'li-phor'i-dæ, from the Greek κάλλος, beauty, + φέρω, to bear, wear, possess; in reference to the beautiful metallic and iridescent colors). German, Schmeissfliegen. Blow-flies, Greenbottle Flies, Bluebottle Flies.

Medium-sized to large, 5-17 mm. long, somber black or dull gray or brilliant metallic blue or green with gold, brass, and copper iridescences; active; wholly terrestrial species; similar in form to the housefly; proboscis fleshy; body usually pollinose, macrochætæ poorly developed or absent on the dorsum; hypopleural bristles present; arista strongly plumose throughout nearly the entire length. Larvæ typically muscoid, up to 17 mm. in length; fleshy nipple-like processes on abdominal segments VIII to X; anterior spiracles with about 10 finger-like processes; posterior spiracular plates nearly circular and with three nearly longitudinal slits which converge slightly inwardly. Puparium with remnants of larval spiracles but with only very small rod-like breathing tubes on the first abdominal segment.

Although this family is a relatively small one from the viewpoint of numbers of genera and species, it is an extremely large one in numbers of individuals which are to be found over very large areas. From the veterinary and medical standpoint the species are very important. The maggots probably cause as much real pain and misery, especially to domestic animals, particularly sheep, as any other group of parasites.

The most important genera are: *Auchmeromyia* Brauer and Bergenstamm, *Calliphora* Robineau-Desvoidy, *Cochliomyia* Townsend, *Chrysomya* R.-D.

¹ Curran includes this family in his family METOPIIDÆ.

(= *Chrysomyia*), *Cordylobia* Grünberg, *Cynomya* R.-D., *Lucilia* R.-D., *Nitellia* R.-D., *Onesia* R.-D., *Phormia* R.-D., *Pollenia* R.-D., *Protophormia* Hough, *Pycnosoma* Brauer and Berg., and *Rhinia* R.-D. It is not possible to discuss all the important species under each genus, so it seems best to list them in groups according to host requirements.

The brilliant metallic blue and green adults of a number of genera are familiar to all and are commonly known as "bluebottles" and "greenbottles" throughout the British Empire and as "bluebottle flies" and "greenbottle flies" in the United States. The most important and best known species are the common bluebottle flies, *Calliphora erythrocephala* (Meig.) and *C. vomitoria* (Linn.), which are large active bristly flies about 10 mm. long. They are saprophagous and widely distributed in Europe and North America. The first is also carnivorous and is nearly cosmopolitan in distribution. *C. auronotata* Macq. and *C. quadrimaculata* Swederus are common in Australia. *Chaetopollenia vespillo* (Fab.), *Micronitellia varia* (Meig.), *Nitellia atromentaria* (Meig.), the cluster fly, *Pollenia rudis* (Fab.), and *Trichopollenia vagabunda* (Meig.), and other species of these genera are parasitic on earthworms in Europe and some in North America. *Onesia sepulchralis* (Meig.) is carnivorous on snails and slugs in Europe. The larvæ of *Protophormia sordida* (Meig.), *P. azurea* (Fallén) (*Phormia*), and other species occur in the nests of birds and suck blood from the nestlings, often killing them. Domestic and wild birds are subject to their attacks.

The most important rôle played by some of these flies is the infestation of sheep caused by the adults ovipositing in soiled wool about the hind quarters and the larvæ attacking the flesh. Very great injury and death may result from their persistent and continued attacks, especially in Australia and New Zealand where the insects are most injurious. The most important species involved are *Calliphora augur* (Fab.), *C. australis* Boisduval, *C. fallax* Hardy, *C. stygia* (Fab.), and the greenbottle flies, *Lucilia cuprina* Wied. and *L. sericata* (Meig.). Many members of the genus *Chrysomya* R.-D. also cause cutaneous myiasis and infest sheep. The most important species are *C. megacephala* (Fab.), a domestic fly abundant in the Oriental, Australian, and Oceanian regions, and China, and *C. micropogon* Bigot, *C. albiceps* (Wied.), and *C. varipes* Macq. which are secondary sheep maggots in Australia. The most important North and South American species is the screw worm, *Cochliomyia americana* Cushing and Patton, dark bluish-green with three dark pronotal vittæ, yellow or reddish face and 5-8 mm. long. The female oviposits in wounds and open sores of man and domestic and wild animals and causes very severe myiasis which may result in death to the host. The related *C. macellaria* (Fab.) is now thought to be a scavenger. The black blowfly, *Phormia regina* (Meig.), 7-8 mm. long, and the greenbottle fly, *Lucilia sericata* (Meig.), occurring in Europe and North America, are responsible for maggoty sheep in the western United States.

The two important widely distributed species attacking man in Africa are the Congo floor fly, *Auchmeromyia luteola* (Fab.) and the tumbu fly, *Cordylobia*

anthropophaga (E. Blanchard). In the former the eggs are deposited in the dust on the floors in native huts and the larvæ, which are pale, deeply segmented, tuberculate, spiny, and up to 17 mm. in length, live in and on the earthen floors. They are nocturnal and suck blood from the legs, feet, and other exposed parts of the sleepers. The tumbu fly, on the other hand, will oviposit on clothing but more frequently on urine- and dung-contaminated soil and in the nests of the common house rat. The maggots bore through the skin and cause cutaneous myiasis in man, especially in the region of the neck and head. The lesions are often tumor- or boil-like and very painful. Domestic and wild animals: cat, dog, horse, mule, goat, camel, rabbit, guinea pig, and others, are also attacked. Breeding may also occur in dung.

Family SARCOPHAGIDÆ¹ (Macquart 1835) Brauer 1889 [Sar'co-phag'i-dæ, from the Greek *σαρκοφάγος*, flesh-eating, carnivorous (*σαρξ*, *σάρκος*, flesh, + *φαγέιν*, to eat); referring to the flesh-eating larvæ]. German, Aasfliegen. Fleshflies, Blowflies, Scavenger Flies.

Medium-sized to large flies; pollinose, bristly, and hairy, usually gray with dark longitudinal pronotal vittæ; silvery, marbled or mosaic and mottled abdomen. Eyes red, large; only approximate in males. Arista plumose from base to or beyond the middle. Proboscis fleshy, straight or slightly curved. Legs stout. Wings and squamæ large. Abdomen bristly with macrochætæ only on the posterior area. Larvæ muscoid type; truncate area of body with several fleshy protuberances; posterior spiracles nearly circular, in a deep depression, each with three nearly parallel slit-like openings.

The members of this large family are among the most interesting and highly specialized flies. Many species are saprophagous, a large number attack the flesh of living mammals, still others are parasitic in a wide variety of invertebrate and vertebrate animals; and a number cause myiasis in man and domestic animals. The adult intestinal flies are very active and all larviposit on the host with much skill in the case of the carnivorous and parasitic forms. The larvæ mature rapidly, and the whole life history usually is not different from that of the housefly. The family consists of some 150 genera and 1,000 species widely distributed throughout the world. In size the adults vary from the small Egyptian *Platyperas quinquestrigata* Enderlein, only 3.5 mm. long, to the gray blowfly, *Sarcophaga carnaria* (Linn.), of Europe, 10–16 mm. long.

Important saprophagous species include the common gray blowfly, *Sarcophaga carnaria* (Linn.), 10–16 mm., and *S. nemoralis* Kramer, 5–11 mm., of Europe; *S. hæmorrhoidalis* (Fallén), 10–14 mm., of Europe and North America; *S. cooleyi* Parker, 10–14 mm., of North America; and *S. aurifrons* Macquart and *S. peregrina* R.-D., the commonest species in Australia. *S. fuscicauda* Boettcher, an abundant Indo-Australian and Oceanian species, also larviposits in open wounds of animals. Members of the genus *Wohlfahrtia* Brauer and Bergenstamm are notorious because the maggots cause cutaneous myiasis in man and domestic animals. *W. magnifica* (Schiner) of Europe larviposits in

¹ METOPIIDÆ Curran 1934, based in part on *Metopia* Meigen 1803, includes this family.

wounds of domestic animals as well as on the head and causes myiasis of the eyes, ears, and nose. *W. vigil* (Walker) of northern North America larviposits chiefly on the skin of infants exposed out of doors and causes severe cutaneous myiasis of the neck and face.

By far the greater numbers of genera and species are parasitic on invertebrate animals. *Sarcophaga heliciis* Townsend of North America and *Helicobosca muscaria* Meigen of Europe are parasitic on snails, and *Sarcophaga davidsonii* Coq. of western United States on spiders and their eggs. *S. hæmorrhoidalis* (Fallén), *S. heliciis* Towns., *S. hunteri* Hough, *S. kellyi* Aldrich, *S. opifera* Coq., *S. tuberosa* var. *sarracenioides* Aldrich, of North America, and *Locustivora pachytyli* Skuse of Australia and the South Pacific Islands are parasitic on grasshoppers or locusts and other orthopterous insects. *S. eleodis* Aldrich, *S. kellyi* Ald., and *S. tuberosa* var. *sarracenioides* Ald. are parasitic on beetles or their larvæ. *S. heliciis* Towns., *S. aldrichi* Parker, *S. prohibita* Ald., and other species parasitize many kinds of insects. Members of the genera *Melopia* Meigen, *MiltoGRAMMA* Meig., and others are parasites or guests in the nests of bees and wasps. The remarkable *Sarcophaga cistudinis* Aldrich of eastern North America causes cutaneous myiasis in turtles and tortoises.

Family TACHINIDÆ Bezzi and Stein 1907 (Ta-chin'i-dæ, from the Greek *ταχινος*, a hare, from *ταχὺς*, swift; referring to the active adults). German, Raupenfliegen. Tachina (tach'i-na) Flies, Tachinid Flies.

Small to medium-sized, robust or slender, active flies which are somber black, gray, brown with lighter markings; hairy or bristly; hypopleural bristles long and arranged in a row. Head large, free. Eyes separated or contiguous in some

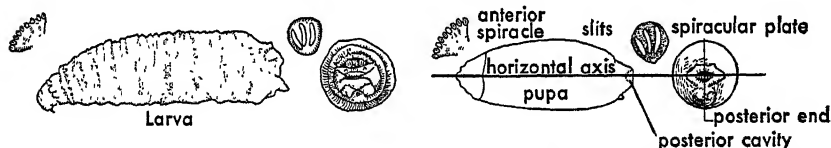


FIG. 301. Larva and pupa of the tachina fly, *Wohlfahrtia vigil* (Walker). (Redrawn from Greene, 1925.)

males. Antennæ arising between or above the eyes. Arista bare or pubescent; three-segmented. Metanotum prominent. Wings large; rarely mottled; first posterior cell narrowed or closed; basal and anal cells closed; squamæ large. Abdomen with conspicuous marginal, dorsal, and apical bristles. Mostly diurnal and many species visit flowers; rarely nocturnal. Oviparous or larviparous with reproductive capacity of 50 to 5,000 eggs or larvæ per female. Larvæ muscoid; cylindrical and tapering anteriorly; distinctly segmented; anterior spiracles small, posterior pair conspicuous; metapneustic in first instar and subsequently amphipneustic. Parasitic forms obtain air directly through an opening in the integument of the host or by connections with the tracheal system of the host.

Pupation occurs within the larval skin, usually in the soil or in the carcass, cocoon, or cell of the host. The eggs or first-stage larvæ are deposited directly on or in the bodies of the host, on the foliage eaten by the host, or in the cells or on the ground in the habitat of the host. The young maggots bore through the integument of the host or enter by means of the genital or anal openings; or hatch from eggs laid on the plants and eaten by the host; or move on the foliage or on the soil and stand erect and cling to the host as it moves over or near them and enter the body as indicated. Once inside the body they become enclosed in a sheath formed by the tissues of the host, which is said to be a primary sheath when cutaneous in origin, close fitting, and when respiration is through a hole in the sheath and the body wall of the host. The secondary sheath is formed from various tissues stimulated by the presence of the larval parasite, and respiration is usually by means of connections with the tracheal system of the host.

The life histories of different species may be exceedingly variable and complicated. A few known forms feed only on the fat body and the blood, void no excrement inside the host, and leave without killing it. Others rupture the sheath in the third instar and rapidly kill the host by devouring the vital organs. It appears that the members are almost wholly parasitic on insects. By far the greatest number of species parasitize the larvæ and pupæ of LEPIDOPTERA and to a much lesser extent the members of other orders as follows: COLEOPTERA, ORTHOPTERA, DERMAPTERA, HYMENOPTERA, DIPTERA, and HEMIPTERA.

The family is a large one consisting of about 300 genera and 5,000 species distributed throughout the world wherever the hosts occur. In North America there are some 190 genera and 1,500 species. In size the adults vary from the small European *Phylomyptera nigrina* Meigen, 3 mm., and the North American *Siphona plusiæ* Coquillett, 3.0–4.5 mm. in length, to the large spiny European *Echinomya grossa* (Linn.) and the American *Paradejeania rutilioides* (Jaenicke), both of which measure 16–18 mm. in length.

The most important genera parasitizing the caterpillars of butterflies and moths are: *Actia* Robineau-Desvoidy; *Ceromasia* Rondani; *Compsilura* Bouché: *C. concinnati* Meigen was introduced into New England from Europe as a parasite of the gypsy moth and brown-tail moth; *Echinomya* Duméril; *Exorista* Meigen; *Frontina* Meigen; *Gonia* Meigen; *Lixophaga* Townsend: *L. variabilis* Coquillett is a parasite of the codling moth in North America; *Masicera* Macquart; *Nemoræa* R.-D.; *Peleteria* R.-D.; *Phorocera* R.-D.: *P. agilis* R.-D. is an important parasite of the gypsy and brown-tail moths in Europe; *Sturmia* R.-D.: *S. sericariæ* Cornalia (*Crossocosmia*) is a parasite of the Chinese silkworm. The eggs are laid on the mulberry leaves and are eaten by the caterpillars and hatch in the body of the host; *S. scutellata* R.-D. and *S. inconspicua* Meigen were also introduced into New England from Europe to aid in the control of the gypsy moth and brown-tail moth; *Tachina* Meigen: *T. larvarum* (Linn.), an Holarctic species attacking a wide variety of large hairy moth caterpillars; *Winthemia* R.-D.: the red-tailed tachina, *W. 4-pustulata* (Fab.),

is also a widely distributed and important Holarctic species which attacks a great many species of caterpillars of moths.

Genera that are parasitic on beetles include *Celatoria* Coquillett; *Centeter* Aldrich; *C. cinerea* Aldrich, an important parasite of the Japanese beetle; *Eleodiphaga* Walton; *Erynnia* R.-D.; *Dionæa* R.-D.; *Lypha* R.-D.; *Myiophasia* Townsend; *Ochromeigenia* Townsend. *O. ormioides* Towns. has been introduced into North America as a parasite of the Japanese beetle. The first-stage larvæ enter the body of the host through the genital or anal openings; *Tachinophyto* Towns.; *Viviania* Rondani (= *Biomya* Rond., *Pseudotractocera* Towns.).

Parasites of the orthopteroid groups include the genera *Acemya* R.-D., *Bigonicheta* Rond. (*Digonochæta*): *B. setipennis* (Fallén) has been introduced

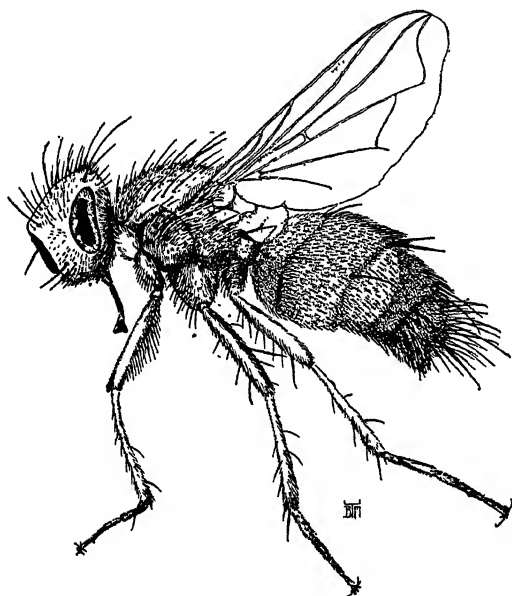


FIG. 302. The tachina fly, *Gonia porca* Williston. (From *Insects of Western North America*.)

from southern Europe into North America and New Zealand to aid in the biological control of the European earwig. It is the most important parasite of this insect. The adults oviposit in the soil in the habitat of the host which may be located by scent and the young active maggots seek out the earwigs and enter the body; *Racodineura* Rond.: *R. antiqua* Meigen is also parasitic on the European earwig. The adults oviposit on the food of the host, and the eggs are eaten by the earwigs and hatch within the alimentary tract. It has been introduced from Europe into New Zealand and parts of North America and elsewhere; and *Stomatomya* Rond.

Genera parasitic on various sawflies, wasps, and other hymenopterous insects

include *Admontia* Brauer and Bergenstamm, *Diplostichus* Brauer and Berg., and *Pachystylum* Macquart.

Especially from the nymphs of bugs have been reared members of the genera *Gymnosoma* Meigen and *Trichopoda* Latr.

Members of the order DIPTERA are only rarely attacked. Species of *Trichoparia* Brauer and Berg. have been reared from crane flies.

Family DEXIIDÆ¹ Macquart 1835 (Dex-i'i-dæ, origin uncertain). German, Schlupffliegen. Dexid Flies.

Species closely related to the TACHINIDÆ in form and habits and separated from them by having the antennæ arising half way between the eyes and the mouth; the hairy or feathered arista; strongly convex metanotum; absence of the presutural intra-alar bristle; ventral abdominal joints concealed below

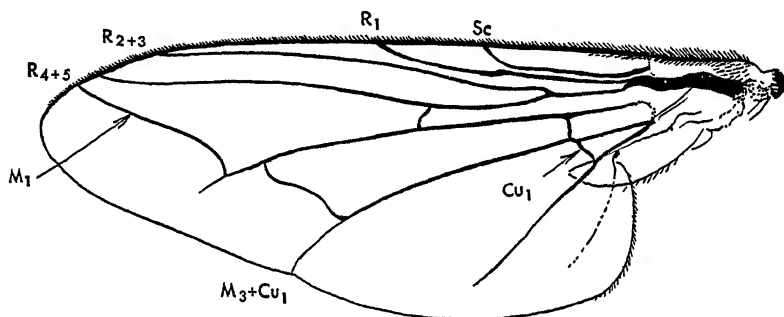


FIG. 303. Wing of *Sturmia distincta* (Wiedemann), a tachinid parasite of caterpillars and chrysalids of moths.

the tergites; relatively long legs. The larvæ are chiefly endoparasitic on the caterpillars and larvæ of beetles.

The family is a fairly large one although less than half the size of the TACHINIDÆ. The most important genera are: *Billæa* R.-D. on larvæ of *Saperda*; *Degeeria* Meigen (= *Medina* R.-D.); *Dexia* Meigen on grubs of *Melolontha*; *Macquartia* R.-D. on macrolepidoptera; *Prosenia* Lepeletier; and Serville: *P. siberita* (Fab.) var. *longirostris* Egger, 5-10 mm., an Eurasian species introduced into North America to aid in the control of the Japanese beetle. The adults larviposit on the soil and the active maggots seek out and parasitize the grubs. Members of the genus *Zophomyia* Macquart are predacious on microlepidoptera.

¹ The family should not be confused with the DIXIDÆ van Wulp 1877, Brauer 1880, which belong in the suborder NEMATOCERA near the moth flies and mosquitoes.

The dark-winged fungus gnats of the family SCIARIDÆ (Billberg 1820) are closely related to the MYCETOPHILIDÆ, suborder NEMATOCERA, and are little known flies confined largely to the holarctic region. The adults frequent damp situations in woodlands and the larvæ frequently travel in great numbers. They feed upon fungi and often destroy mushrooms and seedling plants.

*k. Series PUPIPARA*¹ Nitzsch 1818

(Pu-pip'a-ra, from the Latin *pupa*, girl, doll, + *parere* to bear; bearing pupæ, referring to the method of reproduction.)

Louse Flies, Tick Flies, Keds, Bat Flies, Flat Flies.

These are flies with a more or less leathery integument and usually with the coxæ of the legs widely separated; as a rule they are strongly flattened or in a few cases much compressed in form. The abdomen of the female is always largely membranous and consequently capable of great distention, the ab-

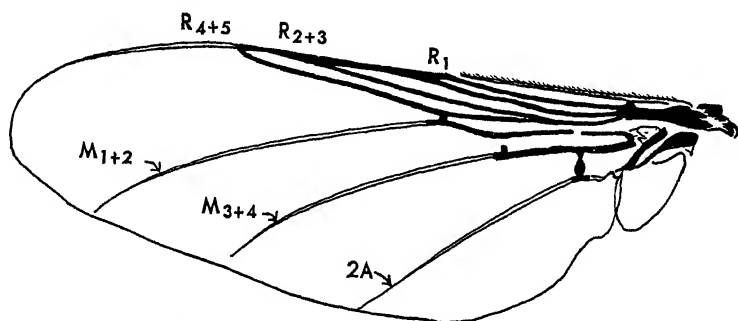


FIG. 304. Wing of a louse fly belonging to the family HIPPOBOSCIDÆ.

dominal segmentation as a result being very obscure. This is generally true of the males also, except in one family, the NYCTERIBIIDÆ, where the male has the abdomen very distinctly segmented and differing very greatly from that of the female. The wings may be entirely absent, they may show various degrees of reduction, or they may be entirely functional. The halteres are sometimes quite small and concealed in a pit but are present in all the forms but one, the sheep tick, *Melophagus ovinus* (Linn.).

The species are all bloodsuckers and live as ectoparasites on birds and mammals. Two of the families are confined to bats. The life histories of but few of the species are definitely known but in these, and probably in all, the larvæ are produced one at a time and are retained in the body of the female where they are nourished by special glands until they are ready to pupate. The larvæ are almost spherical objects and when first extruded are white but rapidly turn brown or black as pupation takes place. They have no mouth parts and the tracheal system is very peculiar. In the only larva of a streblid that has been described in detail there are three large spiracles; in the larvæ of the NYCTERIBIIDÆ there are four small spiracles; in the HIPPOBOSCIDÆ various conditions exist. In the sheep tick there are three pairs of small spiracles at the apex of the body. In other forms the posterior end of the body is formed

¹ Generally considered to be a suborder.

The author is indebted to J. E. Hare for reading and correcting this series.

into a large heavily chitinated plate which is probably the much enlarged and fused stigmatic plate, pierced by numerous minute pores that connect with tracheal branches.

KEY TO FAMILIES

1. Head rising apparently from behind the front coxæ and capable of being folded back upon the dorsum; thorax greatly flattened and expanded; compound eyes, if present, represented at the most by two facets; wings always absent. About 75 species. Found only on bats. (Bat Tick Flies.) **NYCTERIBIIDÆ**
 Head not apparently rising from behind the front coxæ; sometimes flattened but never with the thorax strongly flattened and expanded 2
2. Palpi broader than long, projecting leaf-like in front of the head; wings absent, vestigial, or fully developed, never with the veins crowded toward the costal border. About 50 species. Found only on bats. (Bat Flies.) **STREBLIDÆ**
 Palpi slender and elongate, more or less sheathing the proboscis; wings vestigial in various degrees or fully developed, sometimes caducous or deciduous, with the major veins crowded toward the costal border. Parasitic on birds and mammals other than bats. (Louse Flies, Flat Flies.) **HIPPOBOSCIDÆ**

Family HIPPOBOSCIDÆ Leach 1817 (Hip'po-bos'ci-dæ, from the Greek ἵππος, horse, + βόσκειν, to feed on; referring to the common Old World species which sucks the blood of horses). German, Lausfliegen. Louse Flies, Flat Flies, Forest Flies.

Minute to small, elongate-oval or broad, flat, leathery, hairy, and spiny, apterous or winged ectoparasitic flies which somewhat resemble true lice or even ticks. Head sunken into the emarginate thorax. Proboscis slender, curved, retractile, and hidden. Palpi long and forming a sheath for the proboscis. Eyes oval or round, large. Ocelli present or absent. Antennæ minute; apparently one-segmented (actually three-segmented); arising from pits or depressions near base of proboscis; with or without terminal bristle or long hairs. Thorax little wider than head and narrower than abdomen. Legs short and stout. Tarsi five-segmented, first four very small. Claws large, simple or with one or two teeth. Wings present in one or both sexes, vestigial, or absent; permanent or deciduous; veins strong in subcostal area. Halteres distinct, greatly reduced, or absent. Abdomen broad, rounded or triangular; segmentation indistinct. Only the adults feed, sucking blood from birds, wild and domestic mammals, and occasionally man. Certain species transmit disease organisms to the hosts.

The family is a small one consisting of about 20 genera and 400 species widely distributed throughout the world. In size the adults vary from the small *Ornithoica confluenta* (Say) (= *promiscua* Ferris and Cole) of North America and *O. turdi* Latr. of Europe, which are all 2.5 mm. long, to the large

wallaby louse fly, *Ortholfersia macleayi* (Leach), 10 mm. long, which infests marsupials in Australia.

The most important genera, arranged alphabetically, are:

Hippobosca Linn. which has fully developed wings and halteres and contains nine species. The forest fly, *H. equina* Linn., 7.5 mm., the most important one, is ectoparasitic on horses, asses, mules, cattle, and camels. It is widely distributed in the Old World. *Hippobosca variegata* Megerel  (= *maculata* Leach) occurs on cattle, horses, dromedaries, and camels in Asia; *H. camelina* Leach on dromedaries and horses in Africa; *H. longipennis* Fab. (= *capensis* Olfers) on dogs and other mammals in the Old World; and *H. struthionis* Janson on the ostrich in Africa.

Lipoptena Nitzsch has wings in both sexes which are cast after settling upon the host. *L. cervi* (Linn.) is the common species on deer in Europe. *L. depressa* (Say) and *L. ferrisi* Bequaert (= *subulata* Coq.) infest deer in North America.

Pseudolynchia Bequaert includes the pigeon louse flies: *P. brunnea* (Latr.), North and South America; *P. canariensis* (Macq.) (= *maura* Bigot and *lividicolor* Bigot), cosmopolitan in distribution. These may transmit the coccidium, *H moproteus columb * Kruse.

Melophagus Latr. includes the most important and injurious species in the family, the sheep tick or ked, *M. ovinus* (Linn.), which infests sheep wherever they occur. The adults are dark brown; with long proboscis; without wings or halteres; and 6 mm. long. They greatly irritate the sheep and soil the wool. The puparia are glued to the wool and are generally mistaken for eggs. Development requires from 19 to 24 days. It also attacks chamois, alpaca, and other animals and may transmit *Rickettsia melophaga* N  ller and *Trypanosoma melophagium* (Flu).

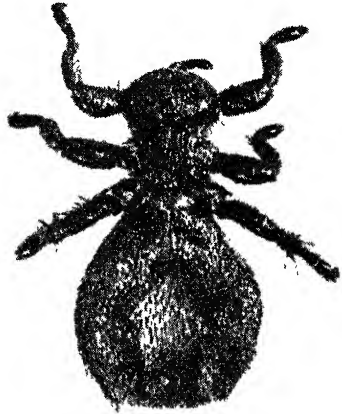


FIG. 305. The sheep tick or hippoboscid fly, *Melophagus ovinus* (Linn.). (Photo by Doten from *Insects of Western North America*.)

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CHAPTER XXXVI

33. Order SIPHONAPTERA¹ Latreille 1825

(Si'pho-nap'ter-a, from the Greek *σίφων*, a tube, + *ἄπτερά*, without wings; referring to these sucking, wingless insects.)
German, Flöhe. French, Puces.

Fleas, Chigoes.

Adults minute to small, apterous, laterally compressed, crawling and jumping insects with complex metamorphosis; piercing and sucking mouth parts; head small; eyes present or absent, simple; ocelli absent; antennæ short, capitate, partially concealed in grooves; legs long and stout; coxæ large; tarsi long, five-segmented; claws one pair, stout; cerci absent. Intermittent blood-sucking ectoparasites of living birds and mammals.

Larvæ worm-like, with well-developed head capsule; biting mouth parts, toothed mandibles; one-segmented antennæ; eyeless; legless; nonparasitic, feeding on animal and vegetable debris.

Adult fleas feed exclusively upon the blood of living birds or mammals, but are able to maintain a free existence for a considerable length of time when in search of a host. Although some are selective, most species are not limited to specific hosts. Species seldom transfer from birds to mammals or vice versa. They might also be grouped as somewhat permanent or as temporary ectoparasites. In the first group are species like the chigoe or burrowing flea, *Tunga penetrans* (Linn.), and the sticktight flea, *Echidnophaga gallinacea* (Westwood), both of which are firmly attached to the host. There is, however,

¹ With other apterous insects, fleas were placed in the order APTERA by Linnæus in 1758. DeGeer (1778) established them in a special section, SUCTORIA, of the APTERA and thus erected a new order for this distinct group of insects. This view was partly concurred in by Retzius (1783), who placed the SUCTORIA in the SALTATORIA, or jumping insects. Latreille (1796) adopted SUCTORIA as a group for the fleas but in 1825 erected his third order, SIPHONAPTERA, for them. Leach (1815) placed fleas in the APTERA in a group which he designated the Century MEDAMOPTERA and also referred to them as the SUCTORIA of Latreille. Samouelle (1819) recognized the order APTERA Leach with the APTERA of Linnæus and Lamarck and the SUCTORIA of Latreille as synonyms. The order APHANIPTERA for the fleas was established by Kirby in 1826 and as synonyms he listed APTERA of Linnæus and of Lamarck, RHYNGOTA of Fabricius, and SUCTORIA of Latreille. Stephens (1829) placed the fleas in the order APHANIPTERA Kirby and erected the family PEDICULIDÆ for them. Many other names such as PULICINA Burmeister (1829), SUCTORIDA Walker (1851), PULICIDA Hæckel (1896), and others still have also been used.

Modern writers have generally used either the name SIPHONAPTERA of Latreille or APHANIPTERA (*ἀφανής*, unseen, invisible, + *πτερά*, wings) of Kirby. Of these two names certainly that of Latreille has precedence. Since the name proposed by DeGeer antedates both, there seems to be no good reason for excluding it in favor of others of more recent origin. It is evident that Retzius, Latreille, Samouelle, Leach, and Kirby all recognized the name SUCTORIA for the fleas, even though they proposed other designations for the same group of insects. In accepting the name SIPHONAPTERA the author is following general usage and not priority.

The author is indebted to M. A. Stewart for reading and making corrections in this chapter.

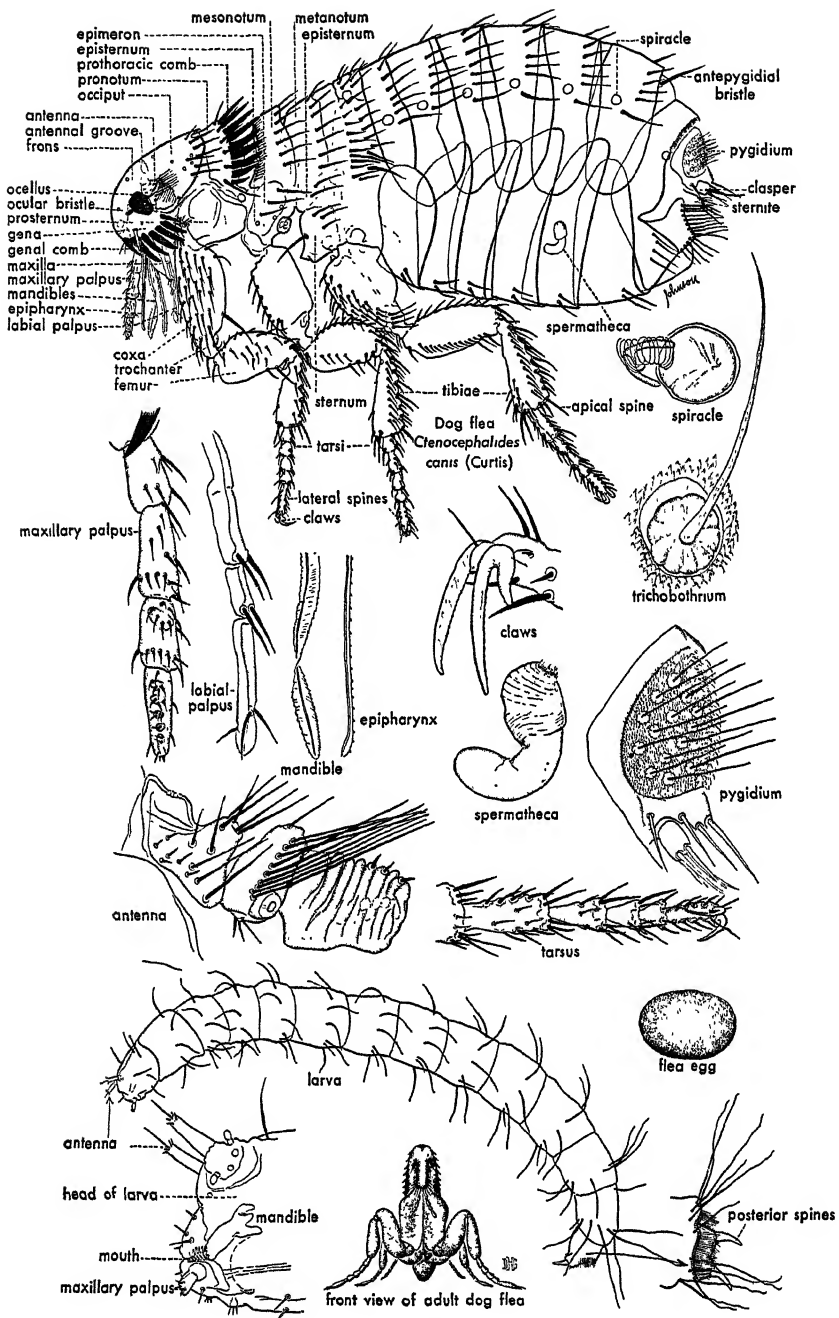


FIG. 306. SIPHONAPTERA or fleas. Various stages and important anatomical characters.

some transfer under normal conditions and a general exodus in case of the death of the host. In the second group belong most of the species which move freely upon the host, in the habitat of the host, or from one animal to another.

Thus the common species of fleas, such as the cat flea, dog flea, rat flea, and human flea, are maintained continuously by domestic pets and rats and are ever ready to take up a temporary abode on man. The extent to which they do this depends upon such factors as climate; municipal, household, and personal sanitation; abundance and cleanliness of domestic animal hosts and their sleeping quarters; the presence of and abundance of rats; and other conditions too numerous to mention. Attention might be called to the fact that such ectoparasites enjoy a comparatively equable and favorable abode on the host where fairly even temperatures prevail, the optimum of which is somewhere between 75° F. and 80° F.

Fleas, next to sucking lice and the bedbug, are the most intimate of man's domesticated animals. They not only inflict pain by their movements and bites which often cause severe irritation and blemishes, but may also cause death by the dissemination of such serious diseases as bubonic plague and endemic typhus fever which are carried from rat to rat and from rat to man. No less than 11 species of fleas are able to transmit bubonic plague. Especially are fleas forced to disperse when the host dies. They are a restless and energetic population ever on the move and ever a source of torment and destruction.

The lower animals and many mammalia such as the marine mammals and sheep are exempt from their attacks.

The eggs are round or oval, normally smooth and shiny, and usually white or pale yellow in color. They are laid among the hairs on the bodies or in the nests of the hosts and are scattered about freely in the nests or in the general habitat of the hosts. Cats and dogs sow them in houses, yards, and other places visited.

The larvæ are small, cylindrical or somewhat flattened, worm-like creatures scarcely more than 5 mm. long when fully matured. The integument is tough and slightly chitinized, the color transparent white or pale yellowish. The *head capsule* is well developed, elongated, chitinized, slightly pigmented and distinctly separated from the thorax; *eyes*, absent; *antennæ*, prominent, one-segmented; often on a basal tubercle; sensory organs present; *moult parts*, biting; *mandibles*, chitinized, three-sided, with two to four teeth; *maxillæ*, large and brush-like on curved stipes and with two-segmented palpi; *labium*, a half circle with one-segmented palpi; *hypopharynx*, small; *thorax*, distinctly three-segmented; *legs*, absent; *abdomen*, 10-segmented with long spines arising from pigmented areas or tubercles; *spiracles*, on the prothorax, metathorax, and abdominal segments I to VIII, inclusive.

The larvæ are nonparasitic and feed upon a miscellaneous diet of the feces of the adults and of vegetable and animal debris in the nests of the hosts and on the floors of human habitations. They have also been able to mature upon a diet of sugar and various foodstuffs in mills, warehouses, stores, and homes where cats and dogs are allowed the freedom of the places. The eggs dropping

from domestic animals sleeping on sacks of sugar, flour, and other materials often result in contamination even if the flea larvæ do not fully develop on the contents.

When fully matured, the larvæ spin small thin disk-like or oval cocoons in which they lie coiled subsequent to and during transformation into the pupal stage. In a comparatively short time the adult form is attained. The complete life history may vary from 28 to 42 days for the human flea in temperate regions, to 21 days for the Indian or tropical rat flea in the tropics, while in temperate regions the time for the latter is retarded to from 27 to 77 days.

Fleas form an isolated and homologous group of insects claimed by some writers to be most closely related to the order MECOPTERA and the DIP-TERA (Tillyard, 1926). The larvæ resemble those of the dipterous family MYCETOPHILIDÆ and the mouth parts of the adults appear to be of the dipterous type but more generalized (Snodgrass, 1935). Martin and Lameer believe they have common origin with the STAPHYLINOIDEA (Stewart).

Fossil fleas have been found in Baltic Amber and in Lower Oligocene of Aix, France. The genus *Palæopsylla* Wagner was taken in the former and *Pulex* (?) in the latter (Schröder, 1926).

Fleas are most abundant in the tropics but also occur in the temperate and even in the polar regions. In comparatively recent times they have been carried into the Sahara Desert and the many Pacific Islands where they were unknown until the advent of civilized man.

There are approximately only 140 genera and 900 species, but the numbers of individuals may be legion. On one small rabbit there may be literally hundreds of fleas present and in hogs' nests I have estimated 500,000. In the temperate regions they are most abundant during the period from June to September and least numerous in January.

There is considerable variance in the classification of these insects. I am following in general that of Ewing (1929) and I. Fox (1940).

IMPORTANT ANATOMICAL CHARACTERS OF THE ADULTS

<i>External</i>	<i>Internal</i>
<p>Size — minute or small; 0.8–5.0 mm. long.</p> <p>Shape — strongly compressed laterally — a character unique among insects; somewhat pointed anteriorly.</p> <p>Integument — tough, strongly chitinated; smooth, shiny, with armature of short stiff setæ, hairs, and sometimes ctenidia or combs — all directed backwards.</p> <p>Color — various shades of yellow, tan, brown, or reddish-brown; some forms almost black.</p> <p>Head — small closely set into thorax without neck; often divided by two or three sutures; sometimes with genal ctenidium and a frontal tubercle.</p>	<p>Digestive System.</p> <p><i>Alimentary canal</i> — <i>buccal cavity</i> or <i>mouh</i> — elongated; <i>pharynx</i> — a chitinated pumping organ; <i>œsophagus</i> — long and tubular; <i>proventriculus</i> — conical, lined with conical pegs or setæ; <i>stomach</i> — fills much of abdomen; <i>Malpighian tubes</i> — four; <i>hind intestine</i> — narrows posteriorly to the rectal sac containing six rectal papillæ; <i>rectum</i> — a long and narrow tube.</p> <p><i>Salivary glands</i> — occupy abdomen and empty at base of hypopharynx or floor of mouth.</p>

External	Internal
<p><i>Eyes</i> — compound eyes absent; or only a single small lens; not faceted; near bases of antennæ. <i>Ocelli</i> — absent.</p> <p><i>Antennæ</i> — short; capitate; appearing three-segmented, but really 11- or 12-segmented; composed of a scape and pedicel and nine- or 10-segmented clavus; fold back into antennal grooves in sides of head; sometimes exhibit sex differentiation.</p> <p><i>Mouth parts</i> — hypognathous; piercing and sucking; extend backwards; and all combine to form a piercing and sucking apparatus; <i>labrum</i> — (labrum-epipharynx) as long as mandibles, blade-like, grooved ventrally; <i>mandibles</i> — long and sword-like, grooved on inner surfaces, serrated apically; <i>maxillæ</i> — usually triangular plates; half as long as mandibles; <i>palpi</i> — long, four-segmented, may be mistaken for antennæ; <i>labium</i> — short; <i>palpi</i> — as long as mandibles, grooved, usually five-segmented, middle segment ringed or divided into two to 17 parts (form sheath for the piercing organs: labrum and mandibles); <i>hypopharynx</i> — absent or very small.</p> <p>Thorax — small and compact; usually not larger than the head; segmentation well defined; pronotal ctenidium on post margin of prothorax of some species; prosternum large.</p> <p><i>Legs</i> — strong; fore and middle pairs rather small, hind pair much larger and developed for jumping; <i>coxae</i> — large and flattened; <i>femora</i> — short, enlarged; <i>tibiæ</i> — almost the size of the femora; <i>tarsi</i> — long, five-segmented, with a pair of strong claws and basal pad.</p> <p><i>Spiracles</i> — a pair on prothorax and a pair between the meso- and meta-thorax; or three * pairs; openings provided with setæ.</p> <p>Abdomen — usually thought to be 10-segmented, but may be 11- or 12-segmented (Wagner, 1932).</p>	<p>Circulatory System. The rather large elongated heart is largest apically and gradually narrows anteriorly and discharges the blood into the thoracic region.</p> <p>Respiratory System. Simple. <i>Spiracles</i> — thoracic — two pairs. abdominal — eight pairs.</p> <p>Nervous System. Normal. Head ganglia; three thoracic ganglia, and seven or eight abdominal ganglia. Connectives variable in length.</p> <p>Reproductive System.</p> <p><i>Male</i> <i>Testes</i> — one pair, fusiform. <i>Vasa deferentia</i> — slender, unite to form common opening into <i>vesicula seminalis</i>. <i>Copulatory organs</i> — complex; chitinized penis; long, curved bristle-like apophyses.</p> <p><i>Female</i> <i>Ovaries</i> — one pair; each consisting of four to eight panoistic ovarioles. <i>Spermatheca</i> — strongly chitinized, often shows through the body wall in cleared specimens and used in classification.</p>

* Tillyard (1926) gives three pairs, and Handlirsch (1926) and Imms (1934) two pairs on the thorax.

IMPORTANT ANATOMICAL CHARACTERS OF THE ADULTS—*Continued*

<i>External</i>	<i>Internal</i>
<p><i>Spiracles</i> — one pair on each segment I to VIII or II to VIII, inclusive. (Some authors give eight and others nine pairs.)</p> <p><i>Cerci</i> — small and unsegmented in the females.</p> <p><i>Genitalia</i> — not prominent.</p> <p><i>Male</i> — claspers on segment IX.</p> <p><i>Pygidial plate</i> — on segment X of male may have sensory organs or trichobothria.</p> <p><i>Female</i> — tergum of segment X bears a stylet.</p>	

KEY TO FAMILIES ¹

1. Thoracic segments not greatly reduced, their combined tergites equal to or longer than the first abdominal tergite 2
 Thoracic segments greatly reduced, their combined tergites shorter than the first abdominal tergite; maxillary palpi as long as fore coxæ; head evenly rounded above **HECTOPSYLLIDÆ**
2. Occipital region without a transverse dorsal suture connecting the bases of the antennæ; frontal margin evenly rounded 3
 Occipital region with a distinct transverse dorsal suture connecting the bases of the antennæ and separating the head into two regions; frontal margin curved at vertex 4
3. Abdominal tergites each with a single row of setæ; eyes usually present **PULICIDÆ** p. 825
 Abdominal tergites each with at least two rows of setæ; eyes may be absent **DOLICHOPSYLLIDÆ** p. 827
4. Antero-ventral flaps absent 5
 Antero-ventral flap present on each side of head opposite mouth (infesting bats) **ISCHNOPSYLLIDÆ** p. 827
5. Occipital region without a dorsal median thickening; frontal region entire; head region spinose, without comb-like row of spines along back margin of the front **HYSTRICHOPSYLLIDÆ** p. 827
 Occipital region with a dorsal median thickening; front region usually divided, the anterior portion bordered with a comb-like row of spines **MACROPSYLLIDÆ** p. 827

Family HECTOPSYLLIDÆ Baker 1904 (Hec'to-psyll'i-dæ, from the Greek *ἑκατόν*, hundred, + *ψύλλα*, a flea).

The members of this small family are more or less permanent ectoparasites in the adult stage and modified for such a life by having a small thorax, small

¹ The two suborders FRACTICIPITA, or broken-headed fleas, and INTEGRICIPITA, unbroken-headed fleas, were erected by Oudemans in 1909, but because of integradations between the two suborders the grouping is of little systematic value.

legs, and greatly enlarged abdomen. Three genera, *Hectopsylla* Frauenfeld, *Echidnophaga* Olliff, and *Tunga* Jarocki, are known although there are a number of other generic names relegated as synonyms of these.

The sticktight flea or tropical hen flea, *Echidnophaga gallinacea* (Westwood), is a serious pest of domestic fowls in many parts of the world. The infestations occur usually on the head of the host at the bases of the bill and comb, around

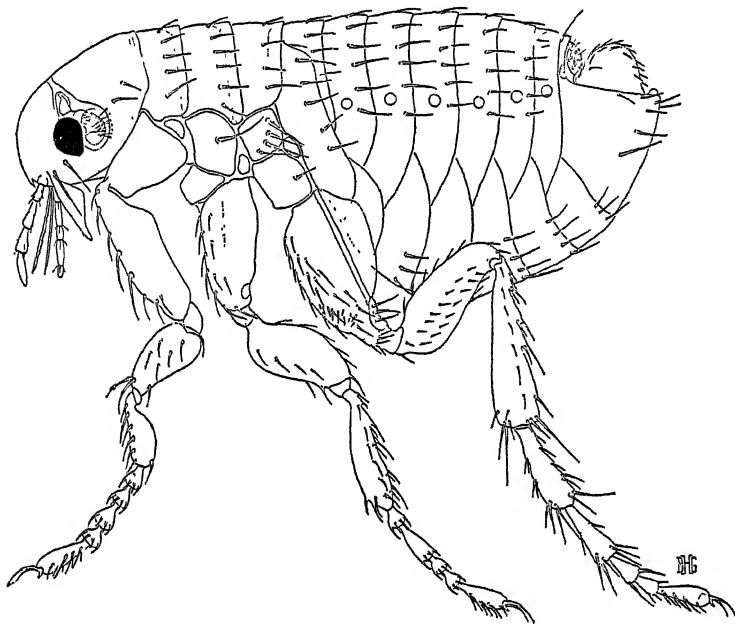


FIG. 307. The human flea, *Pulex irritans* Linn, an Old World species which has become cosmopolitan through migrations. (From *A History of Entomology*.)

the eyes, on the wattles, and on other bare areas. This flea also occurs on wild birds.

The chigoe, jigger, or burrowing flea, *Tunga penetrans* (Linn.), is a small species. The females burrow into the flesh, usually the feet of cats, cattle, sheep, horses, birds, and man. Under the toenails is a favored place on humans, especially on those who go barefooted. It is a tropical South American species which has been carried into tropical Africa and the temperate regions.

Family PULICIDÆ¹ Stephens 1829 (Pu-lic'i-dæ, from the Latin *pulex*, a flea). Common Fleas.

A large family well distributed throughout the world and infesting a wide variety of mammals. The important genera are *Pulex* Linnæus, *Xenopsylla*

¹ Certain members of this family, included in the genus *Archæopsylla* Dampf, are placed in a separate family, ARCHÆOPSYLLIDÆ Oudemans 1909, by some authors.

Glinkiewicz, *Hoplopsyllus* Baker, *Cediopsylla* Jordan, and *Ctenocephalides* Stiles and Collins (*Ctenocephalus* Kolenati).

A familiar and one of the oldest known members of the order is the **human flea**, *Pulex irritans* Linn., which occurs in many parts of the world and infests man, hogs, dogs, rats, skunks, poultry, and other animals. It is, however, not generally so common as the cat flea and the dog flea but it may be exceedingly abundant and noxious in certain places (Essig, 1931).

The **Indian or tropical rat flea**, *Xenopsylla cheopis* (Rothschild), is of great importance because of its rôle in the transmission of bubonic plague from rat

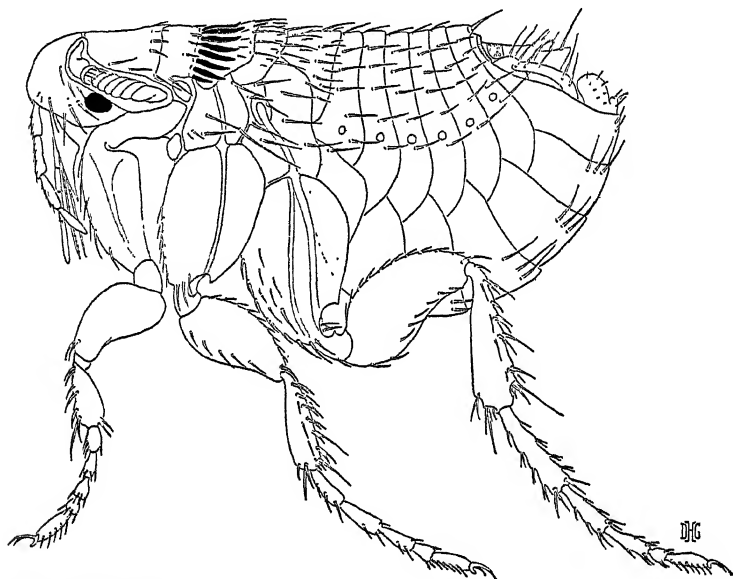


FIG. 308. The European rat flea, *Nosopsyllus fasciatus* (Bosc), an important vector of bubonic plague. (From *A History of Entomology*.)

to rat and from rat to man in the Old World where it commonly infests rats and occasionally man and other mammals.

The **cat flea**, *Ctenocephalides felis* (Bouché), is one of the commonest household pests because it breeds abundantly upon cats, dogs, and rats, and readily attacks man.

The **dog flea**, *Ctenocephalides canis* (Curtis), is often abundant also in the habitations of man and may become a serious nuisance where dogs and cats are not carefully kept free of them.

The eggs of these four species are scattered about the household, shed, yards, and the sleeping quarters of the hosts and give rise to new generations of larvæ, thus affording a continuous supply of adult fleas, unless vigorous and persistent control measures are enforced.

Family DOLICHOPSYLLIDÆ¹ Baker 1905 (Dol'i-cho-psyl'i-dæ, from the Greek *δολιχός*, long, + *ψύλλα*, a flea; from the elongated form).

This is the largest family in the order and includes at least 30 genera and many species.

The ground squirrel flea, *Diamanus montanus* (Baker), infests ground squirrels and the Norwegian rat in parts of western North America and is able to transmit bubonic plague from rodent to rodent. The European rat flea, *Nosopsyllus fasciatus* (Bosc), is capable of transmitting bubonic plague from the wild hosts to man but is a poor vector.

The European chicken flea, *Ceratophyllus gallinæ* (Schrank), (*Ceratopsyllus*), infests fowls in northern Europe and northern United States; the western chicken flea, *C. niger* Fox, occurs on fowls in western North America; and the Canadian chicken flea, *C. gibsoni* Fox, has been taken in Canada.

Family ISCHNOPSYLLIDÆ Wahlgren 1907 (Isch'no-psyl'i-dæ, from the Greek *ισχνος*, slender, thin, + *ψύλλα*, a flea; referring to the slender form).

The members of this family are characterized by a pair of antero-ventral flaps which extend down opposite the mouth on each side of the head.

The eyes are reduced or absent. The 11 genera and many species infest only bats and are the most abundant in the tropics and also occur in the temperate regions.

Family HYSTRICHOPSYLLIDÆ Tiraboschi 1904 (Hys'tri-cho-psyl'i-dæ, from the Greek *ὑστρίξ*, *ὑστριοχος*, a porcupine, + *ψύλλα*, a flea; referring to the spines and ctenidia).

A family in which certain members are either heavily clothed with rows of setæ or spines or have combs of spines on the abdomen and in which the females in some genera have two *receptacula seminis* (spermathecas) which are readily visible in cleared, mounted specimens. The members largely infest rodents.

The mouse flea, *Ctenopsyllus segnis* (Schöenherr), is common on mice and rats and is cosmopolitan.

The wood rat flea, *Hystrichopsylla dipptiei* Rothschild, is a large species, 3–5 mm. long, occurring in the nests of the wood rat in California.

The giant flea, *Hystrichopsylla talpæ* Curtis; 4–5 mm. long, occurs in nests of the European field mouse. It can jump hardly more than an inch.

Family MACROPSYLLIDÆ Oudemans 1909 (Mac'ro-psyl'i-dæ, from the Greek *μακρός*, large, + *ψύλλα*, a flea; referring to the large size).

The members of this small family are grouped into four genera, two of which have only a single species each. They occur only in Australia and South America. *Macropsylla hercules* Rothschild, 5 mm. long, lives on water rats in Australia. *Stephanocircus dasyuri* Skuse inhabits the pouch of the Australian native cat and occurs also on bandicoots in Australia.

¹ Also known by the names CERATOPHYLLIDÆ Dampf 1910 and VERMIPSYLLIDÆ Wagner 1889.

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